Microgrids

Energy Security for Overseas Bases

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Russia's targeting of Ukraine's power grid by Iranian drones and recent increases in natural disasters have highlighted the vulnerability of critical infrastructure and electrical systems worldwide. Disruptions to the power grid from an attack or natural disaster can pose a serious threat to military operations and readiness. To defend against this possibility, Congress needs to direct the Department of Defense to establish renewable microgrids at overseas bases, augmenting efforts already underway by the US Army. Such microgrids will ensure Joint Force resiliency by providing a reliable power source immune to attacks, extreme weather events, and energy market volatility. More importantly, these overseas microgrids will sustain the United States' global military advantage and the defense of US national interests and those of its Allies and partners.

Power grid disruptions from natural disasters or attacks against overseas military installations can pose serious threats to military operations and readiness. Congressional language directing the Department of Defense to establish renewable microgrids, or small local power grids, at overseas locations and authorizing and appropriating the requisite funds will ensure the military's ability to defend US national interests and those of its Allies and partners.

Operating independently of the host nation's electrical grid will provide the military with a reliable power source immune to attacks, extreme weather events, and energy market volatility. More importantly, installing microgrids at overseas locations will make the Joint Force more resilient and capable of ensuring US military advantage and securing the nation's top priorities.[1]

US Power Grid Vulnerability

The severity of threats to power grids at overseas bases is best appreciated by a better understanding of broader domestic power grid vulnerabilities despite the United States' relative geographic isolation from its adversaries. One vulnerability comes from the United States' reliance on fossil fuels for energy production. Approximately 79 percent of domestic energy

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1. Lloyd J. Austin III, *2022 National Defense Strategy of the United States of America* (*NDS*) (Washington, DC: Department of Defense (DoD), October 17, 2022), 18.

production comes from fossil fuels that could be impacted if pipelines fail in an attack or natural disaster.[2] Based on persistent—daily—monitoring of cyber threats to the US power grid by the Department of Homeland Security and the Federal Bureau of Investigation, the greatest cyber threats to the grid are intrusions focused on manipulating the industrial control system networks.[3] These intrusions typically result in malware taking over the industrial control system networks.[4] In fact, concern over vulnerabilities in the US electrical grid drove President Donald Trump to issue Executive Order 13920, declaring a national emergency concerning the threat of foreign adversaries creating and exploiting vulnerabilities in the US bulk-power system.[5]

The United States' energy infrastructure is also susceptible to extreme weather events. California residents struggled through a historic heatwave during the summer of 2022 when they were asked to conserve power in the early evening to prevent blackouts. As temperatures soared, energy officials were concerned the increase in air-conditioning use would overload the energy grid. In fact, power outages from severe weather have doubled over the past two decades across the United States.[6]

These extreme weather events also affect the US military. In February 2021, the Texas power grid failed in the face of Winter Storm Uri.[7] During the storm, several military installations experienced limited power because they relied on local utility providers as their primary source of power.[8] Bases in the region were without power for multiple days, and the outages caused mission impact at each of the bases.

The Biden administration recognized the significance of climate change on national security and issued Executive Order 14008 on January 27, 2021. The executive order states climate considerations would be an essential element of US foreign policy and national security.[9] Specifically, it directs the secretary of defense to consider the implications of climate change in developing strategic guidance documents for the Department of Defense.[10] The executive order was a precursor to the *National Security Strategy*, which identifies

2. US Energy Information Administration, "Consumption and Production, U.S. Energy Facts Explained," last updated August 16, 2023, https://www.eia.gov/.

3. Richard J. Campbell, *Electric Grid Cybersecurity*, R45312 (Washington, DC: Congressional Research Service, updated September 4, 2018), 8, https://crsreports.congress.gov/

4. Campbell, 9.

5. Exec. Order No. 13920, 85 Fed. Reg. 26591 (April 30, 2020).

6. Associated Press, "US Power Outages from Severe Weather Have Doubled in 20 Years," *Guardian*, April 6, 2022, https://www.theguardian.com/.

7. Rachel S. Cohen, "Winter Storm Uri Spotlights Gaps in Military Base Preparedness," *Air Force Times*, March 26, 2022, https://www.airforcetimes.com/.

8. *Installation Resiliency: Lessons Learned from Winter Storm Uri and Beyond, Hearing before the Subcommittee on Readiness of the Committee of Armed Services House of Representatives*, 117th Cong., 1st session (March 26, 2021) (statement of Brigadier General John J. Allen, commander, Air Force Civil Engineering Center, Air Force Materiel Command, Department of the Air Force), https://www.congress.gov/.

9. Exec. Order No. 14008, 86 Fed. Reg. 7619 (January 27, 2021).

10. Exec. Order No. 14008.

climate and energy security as the "existential challenge of our time."[11] Furthermore, in late September 2023, the Department of Energy provided grants to 11 states, tribes, and territories, the latest in over $1 billion in grants this year that are part of the Biden administration's $2.3 billion program to promote power grid resiliency.[12]

The US military is cognizant of the impacts of weather, energy market volatility, and attacks on the energy grid. In its Fiscal Year 2020 *Annual Energy Management and Resilience Report*, the Department of Defense reported 3,018 unplanned utility outages at military installations worldwide (87 percent were electrical) due to various issues.[13] Of the 3,018 outages, 649 lasted eight hours or longer.[14] Unplanned outages have increased each year over the past three years and cost the government an average of $10.2 million annually.[15]

In 2021 the National Academy of Sciences, Engineering, and Medicine acknowledged that

> because there is no way to make power systems completely invulnerable to intentional or accidental physical or cyber disruptions and to the effects of extreme weather events, the nation must move aggressively to create systems that can continue to provide basic services as they recover from disruption.[16]

Power Grid Vulnerability in Conflict

Shortly after the implementation of sanctions on Russia in mid-2022 due to its war in Ukraine, Russia's majority state-owned energy corporation Gazprom reduced its natural gas flow to Europe to 20 percent of its pipeline's capacity.[17] Gazprom claimed the shutdown was required to complete critical repairs to the pipeline. Later, in September 2022 the pipeline shut down completely for additional repairs. The situation grew even more dire after two Gazprom natural gas pipelines located in the Baltic Sea were damaged by explosions on September 26. The disruptions to the pipelines caused natural gas prices to surge and created panic across the European Union.

The disruptions to the natural gas pipelines caused many to speculate Russia was using its natural gas exports as a weapon to combat the sanctions placed on them and influence

11. Joseph R. Biden Jr., *National Security Strategy* (Washington, DC: White House, October 2022), 27, https://www.whitehouse.gov/.

12. Scott Patterson, "U.S. Rolls Out Grants for Power Grid," *Wall Street Journal*, September 29, 2023, A3.

13. Office of the Assistant Secretary of Defense for Sustainment (OASD [Sustainment]), *Department of Defense Annual Energy Management and Resilience Report (AEMRR) Fiscal Year 2020* (Washington, DC: DoD, September 2021), 25, https://www.acq.osd.mil/.

14. OASD (Sustainment).

15. OASD (Sustainment).

16. Committee on the Future of Electric Power in the US, Board on Energy, and Environmental Systems Division on Engineering and Physical Sciences, *The Future of Electric Power in the United States: A Consensus Report of the National Academies of Science, Engineering, Medicine* (Washington, DC: National Academies Press, 2021), 15, https://doi.org/.

17. Associated Press, "Russia to Cut Gas through Nord Stream 1 to 20% of Capacity," AP News, July 25, 2022, https://apnews.com/.

public opinion about its conflict with Ukraine. Russia's actions put the EU in a difficult situation because it relies on Russia for 35 percent of its natural gas.[18] European Commission President Ursula von der Leyen stated, "This is not only a war unleashed by Russia against Ukraine, but this is also a war on our energy, a war on our economy, a war on our values, and a war on our future."[19]

Russia took its battle against energy a step further when it launched extensive attacks against Ukraine's infrastructure. Russian drones struck power plants and substations, creating electricity, heat, and hot water shortages in many cities.[20] As a result of the attacks, Ukrainians were warned to prepare for blackouts and urged to ration energy, because over 30 to 40 percent of the country's total power infrastructure had been impacted.[21]

Global Power Grid Vulnerability

Unfortunately, these are not isolated incidents. Extreme weather has exacted a toll on electrical infrastructure across the world. The flooding that occurred in Libya on September 10 and 11, 2023, is just one of many weather events this year that have killed thousands, displaced millions, and devastated electrical infrastructure throughout the world.

And these threats have implications for US bases overseas. One outage of note created a significant mission impact at Incirlik Air Base, Turkey, in 2016. During the attempted coup in Turkey, the base lost power, resulting in a reduced number of combat missions flown out of the base in support of operations in Iraq and Syria.[22] The base received its power from the local energy grid and had to rely heavily on its emergency generators during the outage. Without the full complement of power on the base, combat operations were reduced, threatening broader American strategy in the region and having impacts beyond just the one installation.[23]

Undoubtedly, US overseas bases are in a situation where they are predominately dependent on host-nation and local energy supplies. Diversifying energy sources and moving toward a localized, US-run energy source—a microgrid—would lessen this vulnerability and increase overall reliability and resiliency. In addition to increased security and

18. Nina Chestney, "What are Europe's Options in Case of Russian Gas Disruption?," Reuters, January 27, 2022, https://www.reuters.com/.

19. Emily Rauhala and Beatriz Rios, "E. U. Proposes Emergency Energy Measures as Russia's War Tests Europe," *Washington Post*, September 14, 2022, https://www.washingtonpost.com/.

20. Dalton Bennett et al., "The Scale of Russian Attacks on Ukraine's Energy Infrastructure, Visualized," *Washington Post*, updated October 17, 2022, https://www.washingtonpost.com/.

21. Phil McCausland, "Ukraine Energy Minister Says Russia Has Hit Half of Country's Thermal Generation Capacity," NBC News, October 21, 2022, https://www.nbcnews.com/.

22. Graham H. Haydon, "Microgrids on Department of Defense Installations: Energy Policy's Impact on National Security" (master's thesis, Johns Hopkins University, December 2019), 5, https://jscholarship.library.jhu.edu/.

23. Haydon.

resiliency, microgrids will reduce transmission and distribution losses and the impacts of volatility in the energy market.

Although the *National Defense Strategy* and executive orders push the military services to build resilience in the face of climate change's significant threat, the military and Congress are not moving fast enough to overcome vulnerabilities to DoD electrical supply and systems.[24] Congress needs to authorize and fund renewable microgrids at DoD overseas installations as soon as possible.

Microgrids

In 2011, General David Petraeus bluntly summarized the military's dependency on power: "Energy is the lifeblood of our warfighting capabilities."[25] To put this into perspective, the Department of Defense is the largest consumer of energy in the United States.[26] Additionally, it is the largest property owner and energy purchaser in the United States with 281,780 buildings encompassing 2.3 billion square feet, generating an energy bill of more than $4 billion annually.[27] Such a high dependence on energy is a major vulnerability for the US military.

With its dependence on energy, the military is constantly searching for a resilient and reliable source of energy to support its mission. The Defense Department has historically relied on host-nation power and stand-alone generators to provide emergency backup power for buildings. In the event of a host-nation power outage, installations have a single backup generator hardwired into the facility at every building housing a critical load.[28]

On large installations, there are often more than 100 small generators dedicated to providing power for facilities during outages. If a base generator fails during an outage, the building is without power until the generator is repaired or replaced, or until power is restored. These generators require monthly preventative maintenance and access to fuel. Installations typically have centrally managed diesel fuel stockpiles that contain enough fuel to run base generators for two to seven days.[29] In a contested area or if fuel shortages exist, it is difficult to secure enough fuel to maintain operations without mission interruption.

The Department of Defense realized the current electrical configuration was a vulnerability and tasked the National Renewable Energy Laboratory to study the effectiveness of backup power systems used on DoD sites in the United States and Canada.[30] The study

24. Austin, *NDS*, 8.

25. Bill Lynn, "Energy for the War Fighter: The Department of Defense Operational Energy Strategy," *White House, President Barack Obama* (blog), June 14, 2011, https://obamawhitehouse.archives.gov/.

26. Neta C. Crawford, *The Pentagon, Climate Change, and War: Charting the Rise and Fall of U.S. Military Emissions*, Costs of War Project (Cambridge, MA: MIT Press, 2022), 2.

27. OASD (Sustainment), *AEMRR*, 6.

28. Jeffrey Marqusee, Sean Ericson, and Don Jenket, *Emergency Diesel Generator Reliability and Installation Energy Security* (Golden, CO: National Renewable Energy Laboratory [NREL], 2020), 4, https://www.nrel.gov/.

29. Marqusee, Ericson, and Jenket, 4.

30. Marqusee, Ericson, and Jenket, 2.

discovered well-maintained generators have a reliability of 80 percent after two weeks of run time.[31] Based on this information, the study determined a single, well-maintained emergency generator cannot guarantee emergency power for critical loads over multiday outages.[32] One way to overcome this vulnerability is for the military to isolate itself from the national power grid: installations can operate microgrids using renewable energy sources as their primary sources of power and use backup generators if the microgrids are impacted.

A microgrid is a localized group of electricity generators with the ability to operate independently from the host nation's electrical grid. The combination of electricity generators, advanced controls, and an energy storage system composes a single, independent, integrated power system. The electricity generators in a microgrid come from a variety of sources, including emergency generators, prime generators, combined heat and power plants, renewables, and batteries.

The ability to separate and isolate itself seamlessly with little or no disruption to loads within the microgrid during a grid disturbance is a key feature of this technology. Microgrids are often considered significant to improving energy resilience for critical infrastructure and services, especially those related to national security and critical community functions.[33]

The term microgrid first officially appeared in the late 1990s when the Department of Energy started to examine electrical grid reliability and resiliency.[34] The Department of Energy started to invest significant money into the concept when it initiated the Smart Grid Research & Development Program. In an effort to optimize grid operations, the program kicked off several demonstration projects aimed at meeting peak load reduction, achieving renewable energy mandates and directives, and maintaining energy surety and reliability at critical facilities, including military installations.[35]

In 2010, the Department of Defense and the Department of Energy entered into a memorandum of understanding to enhance energy security, including grid security.[36] But US interest in microgrids truly blossomed after Hurricane Sandy hit the US East Coast in October 2012.[37] Heightened interest in microgrids stemmed from the results Princeton University received from its microgrid throughout the storm. During the hurricane, Princeton was able to disconnect from the main power grid and maintain power and

31. Marqusee, Ericson, and Jenket, 17.

32. Marqusee, Ericson, and Jenket.

33. US Department of Energy (DoE), *Microgrid and Integrated Systems Program* (Washington, DC: DoE, 2022), 6, https://www.energy.gov/.

34. Martin Anderson, "Microgrid: History, Definition, and Uses," Bridgestone Associates Limited (website), June 25, 2020, https://brdgstn.com/.

35. Dan T. Ton and Merrill A. Smith, "The U. S. Department of Energy's Microgrid Initiative," *Electricity Journal* 25, no. 8 (2012), http://dx.doi.org/.

36. Memorandum of Understanding between the U.S. Department of Energy and the U.S. Department of Defense Concerning Cooperation in a Strategic Partnership to Enhance Energy Security, July 22, 2010, https://www.energy.gov/.

37. Anderson, "Microgrid."

operations within its own microgrid without any interruptions.[38] The microgrid allowed the campus to serve as a "place of refuge" where police, firefighters, paramedics, and other emergency-service workers staged and charged essential equipment.[39] The success of microgrids during Sandy spawned microgrid programs of varying size and complexity in all the states affected by the storm.[40] As of October 2023, there were approximately 687 operational microgrids capable of producing 4,357 megawatts.[41]

Elements of a Microgrid

Storage

One of the most important components of a renewable energy microgrid is an energy storage system. Renewable energy sources like the sun and wind are unpredictable and often suffer from supply interruptions. The nature of renewable sources creates a dependence on storage requirements.[42] The energy storage system works as a buffer and absorbs power when there is a surplus and releases power when there is a deficit.[43]

Having a storage system ensures power quality and availability are not interrupted. Renewable power systems with an integrated storage system can overcome supply interruptions and provide reliable power to its users. It is even possible for a renewable microgrid equipped with a storage system to increase electrical power resilience with better outcomes than using a backup diesel generator.[44]

Control and Load

Microgrids are typically managed through a central controller that monitors the system's operating parameters, coordinates power generation sources, and balances and controls electrical loads. This controller can also connect or disconnect the system from the main grid.[45] In a microgrid with storage, commercial off-the-shelf charge controllers link all power

38. Lisa Cohn, "History of Microgrids in the US: From Pearl Street to Plug-and-Play," Microgrid Knowledge (website), July 22, 2019, https://www.microgridknowledge.com/.

39. Morgan Kelly, "Two Years after Hurricane Sandy, Recognition of Princeton's Microgrid Still Surges," Princeton University Office of Communications, October 23, 2014, https://www.princeton.edu/.

40. John Kliem and Dennis McGinn, "Ingredients for a Microgrid at U.S. Department of Defense Installations," *IEEE Electrification Magazine* 8, no. 4 (2020), https://doi.org/.

41. DoE, "US Department of Energy Combined Heat and Power and Microgrid Installation Databases," US DoE, December 31, 2022, https://doe.icfwebservices.com/.

42. Thomas Price et al., "Microgrid Energy Management during High-Stress Operation," *Energies* 15, no. 18 (2022), https://doi.org/.

43. Beth Burmahl, "Let the Sun Shine: Argonne Technology Enhances Solar Option during Outages," Argonne National Laboratory (website), April 1, 2022, https://www.anl.gov/.

44. Janice Mallery, Douglas L. Van Bossuyt, and Anthony Pollman, "Defense Installation Energy Resilience for Changing Operational Requirements," *Designs* 6, no. 28 (2022), https://doi.org/.

45. Chuck Kirnik et al., *Financing Microgrids in the Federal Sector* (Washington, DC: DoE, 2020), 1, https://www.energy.gov/.

sources and smartly combine them to meet user demand. If the renewable power source is not meeting demand, the control system draws from the battery storage or from another power generator. The controller prioritizes essential loads and prevents mission-critical loads from being shed or interrupted.[46] These control systems also ensure energy is used as efficiently as possible and strive to deliver seamless performance.

Microgrid Energy Sources

Each microgrid is unique in its configuration and energy sources and is designed to solve a specific challenge or meet specific goals.[47] Ultimately, the load on the system defines the microgrid and what energy sources it needs. A microgrid with renewable energy as its primary source is an ideal solution for the military because it reduces the military's reliance on fossil fuels.[48] Few countries are able to produce useable fossil fuels in high quantities. Moreover, relying on other countries for fossil fuels to generate energy creates a dependence that can prove dangerous. Indeed, as climate-related natural disasters become more frequent and severe, microgrids can serve as increasingly valuable resources in support of uninterrupted power for military bases. Additionally, a sustainable microgrid helps the US military reduce its logistical footprint and protects it from attacks on the host-nation electric grid.

Regional

The US military has installations worldwide. The best source for a base's renewable energy microgrid depends on its location. One positive aspect of renewable energy sources is the rapid progress in the field. For example, the Middle East, primarily known as a region committed to fossil fuels, is building renewable energy capabilities. In fact, renewable electricity generation doubled in the Middle East between 2010 and 2020 and is anticipated to double again by 2024.[49]

The United Arab Emirates also plans to receive half of its energy from nonfossil fuel sources by 2050, and Egypt recently completed one of the world's largest solar farms, capable of producing 1.5 gigawatts of energy—enough to power over one million homes.[50] Some of this surge is attributed to the amount of sunlight received in the area and the vast, unpopulated desert, both of which are optimal for collection. As such, the Middle East provides the US military with several potential energy sources for microgrids.

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46. Mallery, Van Bossuyt, and Pollman, "Installation Energy Resilience."

47. Julieta Giraldez et al., *Phase I Microgrid Cost Study: Data Collection and Analysis of Microgrid Costs in the United States* (Golden, CO: NREL, October 2020), 2, https://www.nrel.gov/.

48. Edward Anuat, Douglas L. Van Bossuyt, and Anthony Pollman, "Energy Resilience Impact of Supply Chain Network Disruption to Military Microgrids," *Infrastructures* 7, no. 1 (2021), https://doi.org/.

49. Blain Brownell, "The Coming Renewable Energy Revolution in the Middle East," *Architect*, February 24, 2022, https://www.architectmagazine.com/.

50. "Arab States are Embracing Solar Power," *Economist*, May 7, 2020, https://www.economist.com/.

Solar

Clearly the most cost-effective, reliable, and abundant renewable energy source comes from solar photovoltaics. This technology is attractive because it offers a payback on investment in 2 to 15 years.[51] Generally, the more electricity used on the site and the higher the price for traditional electricity in the area, the shorter the payback period. Costs for photovoltaic systems have decreased by nearly 70 percent in the past 10 years, making them even more attractive.[52] Furthermore, these systems typically require very little maintenance, and while they might be targeted by enemy strikes, solar panel fields can be dispersed and hardened to limit their vulnerability.

Wind

Wind turbines are another renewable energy source available to the US military. These versatile machines can operate independently or be connected to a larger grid or energy system. Wind turbines are one of the fastest-growing energy sources in the world.[53] One reason for the recent growth of wind power generation is that wind is one of the lowest-priced energy sources available today. Furthermore, cost competitiveness in the field continues to improve with advances in science and technology.[54] Much like solar photovoltaics, the cost-effectiveness of the system depends on environmental conditions in the area.

Biomass

Waste disposal and management are critical issues at US military installations and therefore offer another attractive potential source of energy. Recent progress in the waste-to-energy field provides the military with multiple ways to generate energy from waste with minimal impact on health and the environment. The most common method is to incinerate waste with energy recovery. This process generally involves burning waste to boil water, which powers steam generators that make electricity and heat. This regulated method to generate electricity could help resolve security and safety issues caused by transporting waste from the base, while also providing a waste solution that is not harmful to military personnel. Adoption of this method of energy production will depend on its ability to reduce its operating costs and on technology increases.[55]

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51. Will Kessler, "Comparing Energy Payback and Simple Payback Period for Solar Photovoltaic Systems," *E3S Web of Conferences* 22 (2017), https://doi.org/.

52. "Documenting a Decade of Cost Declines for PV Systems," NREL (website), February 10, 2021, https://www.nrel.gov/.

53. Wind Energies Technology Office, "Advantages and Challenges of Wind Energy," DoE (website), accessed November 30, 2022, https://www.energy.gov/.

54. Wind Energies Technology Office.

55. DoE, "Biomass Explained: Waste-to-Energy from Municipal Solid Wastes," DoE, last updated December 28, 2022, https://www.eia.gov/.

Nuclear

Another autonomous power option for the US military is a nuclear microreactor. Microreactors use a small amount of low-enriched uranium to boil water and create steam, which spins a turbine to produce electricity. Placing a small microreactor—one the size of a standard shipping container—into a microgrid would likely provide all the power needed for an entire base. A study conducted on the feasibility of nuclear power at US military installations estimated a 40-megawatt microreactor could meet the electricity needs of about 90 percent of all military installations.[56]

Microreactors gained significant momentum in early January 2021 as a result of Trump's Executive Order 13972, which promoted the advancement of small modular reactors to support national defense and energy security.[57] Today, the Department of Defense is working with private energy companies to install microreactors at its facilities. For example, a pilot program at Eielson Air Force Base, Alaska, calls for a five-megawatt reactor to augment the existing coal and oil power plant and is scheduled to come online in 2027.[58] Yet while this may be a potential microgrid energy source at US bases, it may be politically unfeasible overseas, where proliferation concerns are paramount—though the use of low-enriched uranium limits the risk—and the potential for a direct strike by adversaries exists even if the microreactor is hardened.

Employing Microgrids Abroad

The Department of Defense is working diligently to gain energy security through microgrids at domestic installations. In 2012, it initiated the Smart Power Infrastructure Demonstration for Energy Reliability and Security Programs (SPIDERS) to aid in this process. Since its inception, more than 40 bases have carried out a preliminary study on installing a microgrid, developed plans for installation, or have a microgrid already in place.[59]

In 2018, the Army commissioned a major microgrid project at US Army Garrison Kwajalein in the Marshall Islands. The project, which integrated generators and photovoltaics to produce 2,000-kilowatt hours of energy, provides the base with a microgrid fully independent of the island's energy grid.[60] The success of this project and others led the US Army to identify microgrids as a priority in its strategy to address the impact of climate

56. Thomas Joseph Alford, "Off the Grid: Facilitating the Acquisition of Microgrids for Military Installations to Achieve Energy Security and Sustainability," *George Washington Journal of Energy & Environmental Law* 8, no. 2 (Spring 2017): 116.

57. Exec. Order No. 13972, 86 Fed. Reg. 3727 (January 5, 2021).

58. SAF/IEE Installation Energy, "Eielson AFB Announced as Site for Air Force Micro-Reactor Pilot," Energy, Installations, and Environment, US Air Force (website), October 15, 2022, https://www.safie.hq.af.mil/; and Kelsey D. Atherton, "A Remote Air Force Base in Alaska Is Getting Its Own Nuclear Reactor," *Popular Science*, September 13, 2023, https://www.popsci.com/.

59. Alford, "Off the Grid," 108.

60. Lisa Cohn, "Inside a $40M Army Energy Efficiency Project and Microgrid on the Marshall Islands," Microgrid Knowledge, February 16, 2018, https://www.microgridknowledge.com/.

change on the force. The Army intends to install a microgrid on every installation by 2035 and to pursue enough renewable-energy generation and battery-storage capacity to make its critical mission self-sustaining on all its installations by 2040.[61] The Army is setting the example for the other services to follow in the fielding of microgrids at installations.

Critics of the proposal to install renewable microgrids on military installations say the military's budget should be spent on other priorities to modernize the force and keep pace with China.[62] Yet significant long-term savings in transmission costs and energy efficiency outweigh the short-term costs of installation.[63] Specifically, certain components of a microgrid can be justified economically and paid for out of energy savings or avoided costs.[64]

Furthermore, the United States can look at potential cost-sharing ventures with host nations. Many overseas military installations are shared bases, with United States and host-nation forces occupying portions of the base. Creating a microgrid for all these forces would bolster the national security capabilities of each country. Pursuing this course of action also increases cooperation with US regional and global partners, which results in their increased ability to deter and defend against potential aggression.[65]

Each potential microgrid site is different and requires specific analysis and evaluation to determine how best to implement a microgrid. For example, an old or poorly maintained existing distribution system can impact the reliability of the microgrid system.[66] A recent National Renewable Energy Laboratory study reviewed cost information for 80 microgrid projects and determined associated costs varied, depending on the market segment and complexity of the microgrid.[67] The team concluded the more complex a project, the more expensive it is. Yet while the cost of a microgrid project is important for the military to consider, it would not outweigh the cost of national security and mission impact due to power loss, which is difficult to quantify monetarily.[68]

To overcome potential high microgrid installation costs, the military should conduct a risk and mission analysis assessment of its overseas bases to identify the risk to mission if a power outage occurs at each of its installations. The military has significant expertise in performing these analyses and has most of the necessary information to conduct them

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61. Department of the Army (DA), Office of the Assistant Secretary of the Army for Installations, Energy and Environment, *United States Army Climate Strategy* (Washington, DC: DA, 2022), 6, https://www.army.mil/.

62. Mike Glenn, "Navy Must Speed Up Shipbuilding, Modernization to Keep Pace with China, Russia at Sea, Analysts Say," *Washington Times*, October 30, 2021, https://www.washingtontimes.com/.

63. Rich Castagna, "Microgrids Deliver Resiliency, Security and Savings," IoT World Today (website), January 16, 2020, https://www.iotworldtoday.com/.

64. Kirnik et al., *Financing Microgrids*, 1.

65. Austin, *NDS*, 8.

66. Kirnik et al., *Financing Microgrids*, 4.

67. Giraldez et al., *Phase I*, v.

68. Christopher J. Peterson et al., "Analyzing Mission Impact of Military Installations Microgrid for Resilience," *Systems* 9, no. 3 (2021): 1, https://doi.org/.

quickly. Addressing the most critical installations first ensures the United States is using its money for the greatest benefits.

Part of this risk assessment should consider the energy production, sustainability, and energy storage of a potential microgrid as well as the installation's weather, purpose, size, and distance from the local utility provider.[69] An analysis of these factors provides decisionmakers with an understanding of the impact a microgrid will have on the base's energy resiliency before determining the type of microgrid to install.[70]

Once the bases are identified, the military must evaluate each base and identify its critical facilities. At each base, the military should identify the mission each facility contributes to, the load associated with conducting the mission, and the impact any loss of power would cause on mission accomplishment.[71] The second step in this analysis involves determining the set of scenarios that could disrupt the power supply and estimating the probability of each event occurring.[72] Performing this second level of analysis helps microgrid designers understand how to develop a microgrid capable of ensuring the highest probability of mission accomplishment.

One critical scenario for any military base is the potential for attack. Large solar photovoltaic fields and wind turbines are attractive targets for enemy forces. Hardening the electrical infrastructure or dispersing it to various locations throughout the base are ways to overcome this vulnerability. One possible way to disperse a photovoltaic field is to place solar panels on buildings throughout the base. Not only does dispersal make the grid a harder target to hit, but it also increases the ability of a base to provide power reliably and redundantly to its critical facilities.

Lastly, one major benefit of the burgeoning renewable energy sector is the decreasing cost of such systems due to its prevalence in the energy sector. The US Energy Information Administration reported electricity generation from renewable energy exceeded coal for the first time in April 2019. Even with the increase in prices for materials, shipping, and labor, the cost of renewable energy systems is roughly 40 percent less than building a coal or gas plant.[73] Battery energy storage systems are also decreasing in price, and the average global lithium-ion battery pack price has declined significantly since 2010.[74]

Microgrid costs are also trending downward as the system gains popularity in the commercial sector. Currently, microgrids make up 0.2 percent of the electricity generation of the national electrical infrastructure, but 2016 to 2019 saw a yearly increase of 62 to 68

69. Haydon, "Microgrids," 17.
70. Haydon.
71. Peterson et al., "Analyzing Mission Impact," 4.
72. Peterson et al., 5.
73. David R. Baker, "Renewable Power Costs Rise, Just Not as Much as Fossil Fuels," Bloomberg, June 30, 2022, https://www.bloomberg.com/.
74. Eric Lightner et al., *Voices of Experience: Microgrids for Resiliency* (Golden, CO: NREL in conjunction with Smart Electric Power Alliance, 2020), 42.

percent in the numbers of microgrids installed.[75] Furthermore, Department of Energy research and development targets for microgrids anticipate electricity generation capacity will be more distributed in nature, with capacity in 10 years likely being 30 to 50 percent distributed energy assets.[76]

Conclusions

Department of Defense policy dictates all military bases must insure they have reliable power to carry out their critical missions.[77] Russia's war in Ukraine highlights the vulnerability of relying on nonrenewable sources of energy for national security. Russia is using energy as a weapon against the resolve of the EU and its allies and partners and attacking the Ukrainian electrical infrastructure. If key US bases around the world are not able to access power, they will not be able to support combatant commanders in the defense of national interests and the safety and security of US Allies and partners. Although the Department of Defense recognizes the importance of reliable power, it is not implementing innovative solutions like microgrids quick enough.

Congress can help increase energy security and reliability in the military by mandating microgrids at overseas bases and providing funding to enact this mandate. US code already encourages the Department of Defense to "consider, when feasible, projects for the production of installation energy that benefits military readiness and promotes installation security and energy resilience."[78] The code elaborates on the direction provided and defines ways to increase security and energy resilience as "incorporation of energy resilience features, such as microgrids, to ensure that energy remains available to the installation even when the installation is not connected to energy sources located off the installation."[79]

These statements are helpful but need to be more directive, like the language in the US code regarding energy security for military installations in Europe. The Fiscal Year 2020 National Defense Authorization Act directed the secretary of defense to "ensure that each contract for the acquisition of furnished energy for a covered military installation in Europe does not use any energy sourced from inside the Russian Federation as a means of generating the furnished energy of the covered military installation."[80] The language provides the defense secretary an opportunity to waive the requirement as long as the Defense Department requires the energy to meet mission requirements and the risks associated with the decision are evaluated.

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75. Summer Ferreira et al., *DOE OE 2021 Strategy White Papers on Microgrids: Program Vision, Objectives, and R&D Targets in 5 and 10 years–Topic Area #1* (Washington, DC: DoE, April 2021), 10, https://www.energy.gov/.
76. Ferreira et al., 5.
77. Marqusee, Ericson, and Jenket, *Emergency Diesel*, 3.
78. 10 U.S.C. § 2911(h).
79. 10 U.S.C. § 2911(h)(B).
80. 10 U.S.C. § 2911.

Once Congressional language is in place, the first place to start is the most mission-critical overseas bases. Based on the *National Defense Strategy*, it is likely these bases will be in areas with the most impact on the United States' great power conflict with China and Russia. For example, the US Air Force is increasing the number of its bases across the Pacific over the next decade, to spread out and become more survivable in conflict.[81] Adding a microgrid to these new bases will increase survivability and the Air Force's ability to generate an air tasking order if the base encounters host-nation power interruptions.

Some countries where US bases are located are highly interested in international investment in solar projects.[82] This presents the United States with an opportunity to invest in solar projects on military bases and share the technology with its Allies and partners. Evidence of this occurred in early November 2022 when the United Arab Emirates and the United States signed a partnership to spur $100 billion of investments in clean energy projects and add 100 gigawatts of clean energy globally by 2035.[83] The agreement pushes each country to assemble and stimulate private and public sector funding for clean energy innovation, carbon and methane management, advanced reactors, and industrial and transport decarbonization.[84]

Power grid interruptions from a natural disaster or attack pose a risk to military operations and readiness. Congressional language authorizing and funding renewable microgrids at overseas locations will ensure the US military continues to defend our national interests and that of our Allies and partners. Operating independently of the host nation's electrical grid will provide the military with a reliable power source immune to attacks, extreme weather events, and energy market volatility. Ultimately, powering overseas installations with microgrids will enable Joint Force resiliency and secure continued US military advantage.[85] ✈

81. Audrey Decker, "Air Force Expanding Number of Bases in Pacific over Next Decade," Defense One, August 29, 2023, https://www.defenseone.com/.

82. Samuel Humphries, "A Bright Future: The Middle East's Solar Revolution," American Security Project (website), June 30, 2020, https://www.americansecurityproject.org/.

83. "UAE and U.S. Reach Deal for $100 Billion in Clean Energy Projects," Reuters, updated November 2, 2022, https://www.reuters.com/.

84. "UAE and U.S."

85. Austin, *NDS*, 18.