H.R. 2759: Department of Defense Climate Resiliency and Readiness Act

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EXECUTIVE SUMMARY

H.R.2759, the Department of Defense (DoD) Climate Resiliency and Readiness Act, (hereinafter referred to as 'proposed DoD Climate Act'), aims to incorporate renewable energy and climate resiliency to support non-tactical aspects of the military. This report assesses the feasibility of this goal, drawing on research of renewable technologies, climate science and existing initiatives of the DoD. To succeed, scientific measures in the proposed DoD Climate Act will be utilized after its enactment. In transitioning the DoD towards climate resilience and renewable energy, the proposed DoD Climate Act establishes a goal of reaching net zero greenhouse gas emissions for non-operational sources by 2030; directs the DoD to set ambitious interim targets to meet or exceed that goal; and calls for a centralized function of the DoD to combat climate change. Moreover, it will also accelerate the decarbonization of the U.S. economy and profoundly reduce national emissions. Scientific evidence confirms that human activities are the cause of global warming and climate change. Since 1880, humans have increased atmospheric carbon dioxide by approximately 45%, contributing to the greenhouse gas (GHG) effect and warming the planet by 1.9˚ Fahrenheit (1˚ Celsius).[i]

Both the current and projected impacts of our planet's warming are unprecedented in scale. In recent years, the DoD has spent billions of public funds to repair military installations impacted by extreme weather, with damages projected to significantly increase as climate change progresses.

In response, the proposed DoD Climate Act provides formal risk management practices to prepare non-operational military installations for extreme weather events. To this end, the proposed DoD Climate Act requires the DoD to adequately assess and fortify against the complex physical threats posed. A climate vulnerability score will therefore be determined for each military installation and DoD building. Using this standardized tool, required adaptation measures will reduce the identified vulnerabilities. It is critical for the DoD to continue to fortify installations and ensure the resilience of domestic military infrastructure against climate change to preserve national security. The proposed DoD Climate Act works to both nullify the source of its climate risks through mitigation efforts as well as respond to existing threats through adaptation and resiliency efforts.

To address this, the proposed DoD Climate Act requires the DoD to reduce its own contribution to climate change. As noted, the proposed DoD Climate Act requires all non-operational installations of the DoD to improve energy efficiency and achieve aggregate net zero energy consumption by 2030. The proposed DoD Climate Act, as a part of this effort, requires further investment in the development of microgrid energy systems. These systems grant the DoD further control and flexibility to incorporate renewable energy sources, while also enhancing the DoD's energy security by allowing installations to operate independently of the civilian electrical grid. With our current infrastructure, a failure in the national power grid would limit the military's ability to effectively respond to extreme weather, natural disasters, or conflict with foreign powers. Thus, a strategy for reliable energy infrastructure and localized microgrids is critical for DoD installations.

The implementation of the proposed DoD Climate Act will only be successful if the DoD demonstrates increased climate resiliency and 100% net zero energy by 2030. To ensure that these goals are met, the DoD must routinely measure its progress at each installation, specifically monitoring its carbon dioxide and other GHG emissions. Additional measurements of success include further implementation of renewable energy projects at installations and increasing research investment allocated to the development of renewable energy technology, including but not limited to microgrids and battery storage. It is essential that progress be measured with science-based key performance indicators to objectively determine and drive the success of the proposed DoD Climate Act.

INTRODUCTION TO THE PROPOSED DOD CLIMATE

Introduced on May 15, 2019 by Rep. Veronica Escobar (D-TX-16) to the Committee of Armed Forces, the proposed DoD Climate Act has since been sponsored by four other House Representatives, all of whom agree that climate change is an imminent threat to the DoD. If enacted, the proposed DoD Climate Act will require the Secretary of Defense to amend the structure and operations of the DoD to secure their energy resources in preparation for challenges relating to climate change. The primary goal of the proposed DoD Climate Act is to restructure the DoD's energy sources to achieve net zero energy by December 31, 2029. After its introduction, the House of Representatives referred the proposed DoD Climate Act to the House Committee on Armed Services. From there it was referred to the Subcommittee on Readiness, where it has remained since May 16, 2019. The proposed DoD Climate Act focuses on five major goals and provisions, enumerated below:

1. The DoD must implement climate-conscious budgeting and purchasing in conjunction with its contractors.
2. The Secretary of Defense must develop a strategy to incorporate climate resiliency into existing strategies and operations.
3. The Secretary of Defense must provide a strategy for transitioning all non-operational sources of the DoD to meet the goal of net zero energy by December 31, 2029.
4. The DoD is required to continue with research, development, and demonstration of microgrid systems for electric generation and storage.
5. Within 180 days of enactment, the DoD must develop a Climate Vulnerability and Risk Assessment Tool to assess how the risks associated with climate change impact its operations and installations.

Key Definitions

- *Resiliency*, with respect to each installation of the DoD, is the anticipation, preparation for, and adaptation to withstand or prevent utility disruptions and changing environmental conditions.[2]
- *Net Zero Energy* occurs when an installation produces as much energy as it uses over the course of a year. The proposed DoD Climate Act pursues net zero energy as a reduction in overall energy use, a maximization of energy efficiency, the implementation and use of energy recovery and cogeneration capabilities at each installation, and an offset of the remaining demand for energy with the production of energy from on-site renewable energy sources.[3]
- *Non-operational sources* (i.e., installation energy) are energy-emitting or energy-consuming assets of the DoD which include those fixed military bases or

infrastructure that do not support combat operations, as well as non-tactical military vehicles that are not used for such operations.[4]

- *Operational sources* are DoD installations or resources which are utilized for training, moving, and sustaining the Armed Forces and weapon platforms for military operations. For example, tactical power systems and generators at non-enduring locations are included as operational sources.[5]
- *Renewable energy source* is defined in section 2924(6) of title 10, United States Code, as energy generated from renewable sources including (a) solar, (b) wind, (c) biomass, (d) landfill gas, (e) ocean, including tidal, wave, current and thermal, (f) geothermal, including electricity and heat pumps, (g) municipal solid waste, (h) new hydroelectric generation capacity, and (i) thermal energy generated by any of the preceding sources.[6]
- *Microgrid system* refers to a standalone electrical system that uses grid-scale energy storage.[7]
- *Hybrid microgrid system* is a standalone electrical system that consists of conventional generation and at least one alternative energy resource. The hybrid microgrid may also incorporate grid-scale energy storage.[8]
- *Climate change* is defined in the DoD Dictionary 4715.21, as variations in average weather conditions that persist over multiple decades (or longer) that encompass increases and decreases in temperature, shifts in precipitation, and changing risks of certain types of severe weather events.[9]

THE SCIENTIFIC PROBLEM: CLIMATE CHANGE

Since 1880, global temperatures have warmed by 1.9 degrees Fahrenheit (1 degree Celsius) and carbon dioxide levels have increased by 125.59 ppm (43% increase from 290.8 ppm in 1880 to 416.39 in June 2020).[10] The overwhelming majority of the scientific community agrees that this increase in atmospheric concentrations of carbon dioxide and other greenhouse gases since the Industrial Revolution is due to anthropogenic causes (i.e., human activity). According to the 2014 Intergovernmental Panel on Climate Change synthesis report, atmospheric carbon dioxide levels resulting from human activity are rapidly accelerating, with nearly half of the carbon dioxide emissions between 1750 and 2011 occurring in the last 40 years.[11] This increase in atmospheric concentrations of GHG, and carbon dioxide in particular, is dramatically propelling anthropogenic climate change.

Temperature on Earth is determined by the amount of sunlight absorbed by the planet. Absorption of sunlight can vary based on the amount of sunlight that reaches the Earth (solar radiation), the amount of sunlight reflected by the Earth's surface (albedo), and the amount of sunlight absorbed in the atmosphere due to GHGs. The greenhouse effect is the process by which energy from the sun is trapped by carbon dioxide and other GHGs. GHGs prevent reflected shortwave energy and radiated longwave energy from escaping to space; this energy is then sent back to the Earth's surface, repeating the process, and ultimately heating the planet.

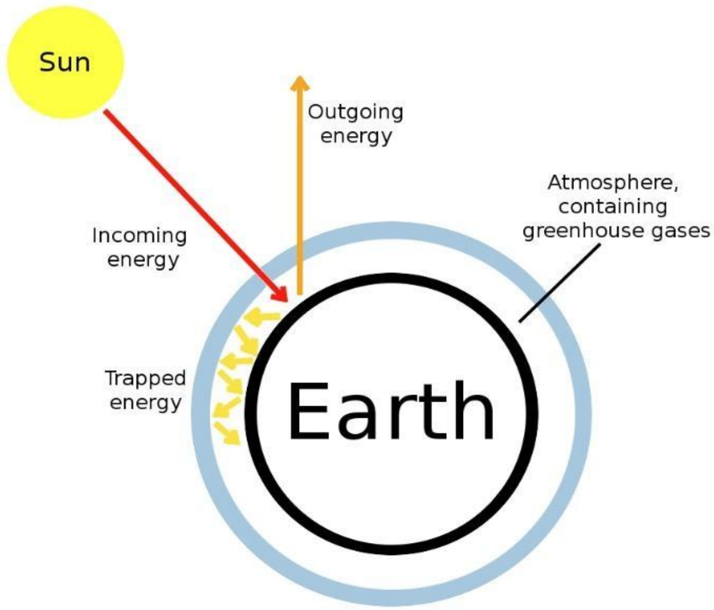

Figure 1: The Greenhouse gas effect on Earth

Projected physical risks associated with climate change include global sea level rise, increased flooding, extreme precipitation, extreme weather events, extreme heat, water stress/drought, desertification, and permafrost thaw. The following subsections will discuss how the specific threats of global sea level rise, flooding, drought, and water shortages are projected to impact the DoD.

Global Sea Level Rise and Flooding

Over 1,700 U.S. military installations are currently at risk of flooding due to global sea level rise, a condition caused by increased temperatures. [12] As the world's oceans warm, water molecules expand and the volume of the water in the oceans increases.[13] At the same time, the melting of glaciers and land ice causes more water to drain into the ocean. A report published by the National Oceanic and Atmospheric Administration (NOAA) in July 2020 reported that sea level rise is already affecting U.S. coastlines, with many coastal areas experiencing regular tidal flooding wherein ocean waters reach 0.5 to 0.65 meters above the normal high tide.[14] NOAA scientists predict that the extent, frequency, and depth of coastal flooding will continue to increase.

In addition, climate change will intensify and increase the frequency of extreme weather events. Coastal cities rely on the military to provide rescue and other essential services to residents in the aftermath of extreme weather events.[15] During such events, global sea level rise will increase the severity of storm surge and flooding, posing physical risks to coastal civilian and military infrastructure. For example, in 2014, Fort Irwin in California reported $65 million in damages from flooding.[16] Additionally, in 2018, Hurricane Michael caused $5 billion worth of damages to Tyndall Air Force Base in Florida, crippling the installation's infrastructure.[17] In 2017 alone, hurricanes Harvey, Irma, and Maria cost the federal government an estimated $1.3 billion dollars.[18]

Figure 2: Tyndall Air Force Base after Hurricane Michael 2018

Drought and Water Shortages

Climate change can cause shifts in rainfall patterns globally, sometimes exacerbating drought conditions in already arid regions. According to a 2019 report from the Government Accountability Office (GAO), there are more than 100 military installations at risk of water shortages, an increase of seven bases from previous DoD reports.[19] Installations most at risk are located in Arizona, California, and New Mexico––states that experience ongoing drought conditions. Water scarcity, as defined by the GAO, occurs when the demand for water exceeds its supply. Referencing the National Climate Assessment, the GAO acknowledged that drought as the result of climate change will worsen water scarcity at installations across the country.

The lack of precipitation and moisture in the ground will reinforce and perpetuate dryness, a positive feedback loop. Drought and increased wind can increase the severity of wildfire activity, resulting in impacts to DoD infrastructure. According to the 2019 *Report on Effects of a Changing Climate to the Department of Defense*, wildfires remain a constant concern to many military installations.[20] Wildfires can cause physical damage to the electric grid infrastructure and disrupt power service.[21] By way of illustration, in September 2016, the Canyon Wildfire burned 10,000 acres at Vandenberg Air Force Base in Santa Barbara, CA, resulting in a loss of electricity at buildings on the Air Force Base.[22]

DoD Greenhouse Gas Footprint

The DoD is the world's single largest producer of GHG and the U.S. military is the world's largest institutional consumer of oil.[23] Accounting only for emissions from fuel usage, if the U.S. military were a nation state, it would be the 47th largest emitter of GHG in the world.[24] Non-operational installations account for 30% of the DoD's energy use.[25] In 2016, non-operational forces consumed approximately 360 trillion British thermal units. As of 2017, the DoD consumed 77% of the federal government's energy, with the greatest proportion of military GHG emissions originating from its buildings and fuel use.[26]

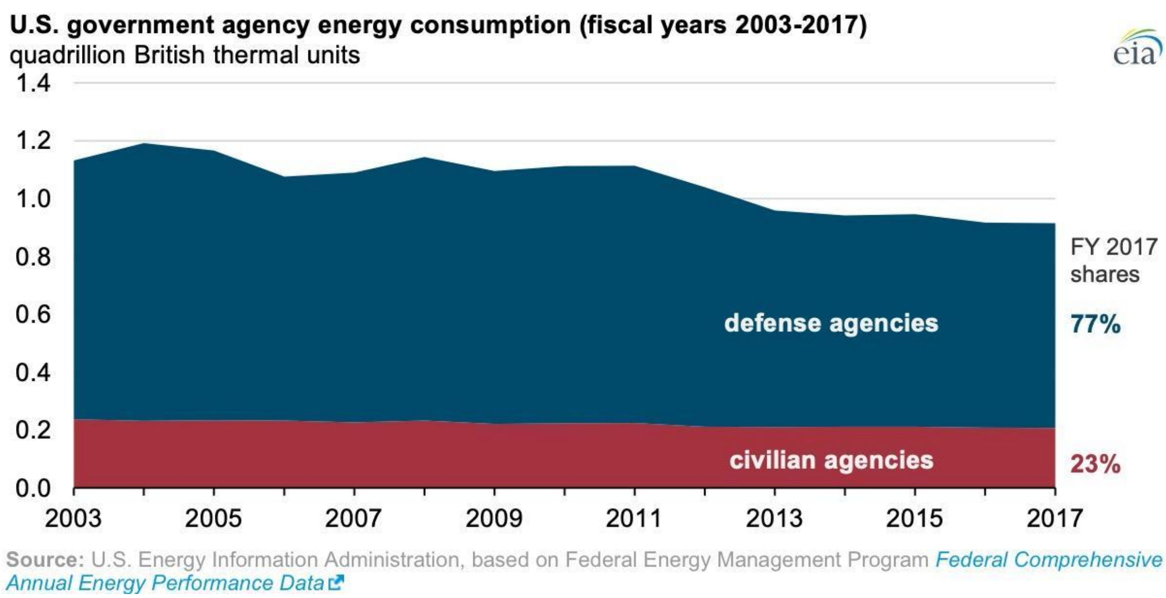

Figure 3: U.S. federal government energy consumption (2003-2017)

SCIENTIFIC SOLUTIONS TO THE IMPACT OF CLIMATE CHANGE

The solutions in the proposed DoD Climate Act consider the ramifications of climate change on DoD installations as well as the importance of energy infrastructure and reliability. The proposed DoD Climate Act requires the implementation of climate risk mitigation strategies guided by the development of a climate risk assessment tool and carried out through interagency cooperation. At the same time, it stipulates that the DoD must work to achieve net zero energy at non-operational sites, in order to improve energy security while reducing its own contribution to climate change. These solutions aid the DoD in adapting to climate change while also utilizing the DoD's economic influence to establish best practices in energy resiliency through climate conscious spending.

Climate Risk Management

The proposed DoD Climate Act prioritizes climate risk management in strategic planning, budgeting, and operational decisions. It also provides the resources for a standardized climate vulnerability and risk assessment protocol across the DoD and necessitates the creation of a formal risk management system. Specifically, a risk management system would integrate climate adaptation best practices to the most vulnerable installations as well as require the placement of future installations in areas less susceptible to climate risks. Thus, the risk management requirements in the proposed DoD Climate Act will decrease the DoD's overall climate risk by increasing its capacity to handle existing exposure, in addition to reducing its future susceptibility to physical climate change threats.

The proposed DoD Climate Act requires that the DoD develop a Climate Vulnerability and Risk Assessment Tool within 180 days of enactment to measure the risks associated with climate change. The tool will incorporate science-based climate change models to project physical risks from climate change on DoD networks, systems, installations, facilities, and other assets. It will include a standardized system to assign a climate vulnerability score to each military non-operational installation, as well as identify the top ten most at risk installations. More importantly, this tool will allow the DoD to incorporate science-based projected climate change impacts into long-term strategic planning.

The DoD will then assess how exposure will impact food, housing, and training availability. Assessments will also determine how these site-specific exposure factors affect the physical infrastructure or operational continuity of an installation. Subsequently, the DoD will need to implement resiliency measures such as updating infrastructure to mitigate risks of flooding and sea level rise. The DoD will also need to coordinate with international partners to ensure that resiliency is prioritized at all DoD installations globally. This solution provides the framework for the DoD to manage and reduce the physical risks climate change poses to its installations and operations and bolsters the DoD's ability to fulfill its mission of maintaining national security.

Net Zero: Energy Efficiency and Renewable Energy Sources

In order to improve energy security and address the DoD's own role in contributing to climate change, the proposed DoD Climate Act requires non-operational DoD installations to achieve aggregate net zero energy consumption by December 31, 2029. Based on an analysis of fuel consumption, between 2001 and 2017, the DoD emitted an estimated 1.2 billion metric tons of greenhouse gases, more than any other department of the federal government and more than the total produced by most entire nations.[27] Non-operational forces currently account for 30% of the DoD's total energy usage.[28] This massive energy footprint is largely the result of burning fossil fuels at centralized electrical production facilities which power many of the DoD's fixed installations. This not only generates emissions which intensify the burden of climate change but leaves the DoD especially vulnerable to the volatility of fossil fuel supply and at risk of service disruption from natural disasters or other threats to those central power grids.

To mitigate these risks when reliant on a carbon-intensive commercial electricity sector~~,~~ the proposed DoD Climate Act requires actions to maximize energy efficiency while also investing in a transition to renewable energy sources to supply the remainder of its energy needs. The DoD has previously recognized the need for energy efficiency at its installations, having reduced site-delivered energy consumption by 20% between the years 2003 and 2017, resulting in a savings of over $5.6 billion which drove the majority of federal energy efficiency improvements during that time.[29] However, this still falls short of the 30% reduction that was targeted by 2015. Moreover, the DoD has continuously failed to achieve many of its complementary efficiency targets, as noted by the report cards issued by the Office of Management and Budget.[30] This leaves ample opportunity for improvement, with the same reports showing that, as of 2018, only 2% of buildings evaluated had achieved sustainability criteria, with more than half of potential facilities yet to be assessed for potential improvements. Concurrently, the DoD has made significant progress in the realm of fleet fuel efficiency, which presents additional opportunities since these improvements can result in saving millions of dollars and hundreds of thousands of gallons of oil each year.[31]

In order to meet the persistent energy consumption needs of the DoD, the proposed DoD Climate Act focuses on the potential of solar, wind, and hydro-powered electricity sources as a means of renewable energy production. Solar photovoltaic (PV) systems produce energy by converting sunlight into electricity using semiconductors that absorb sunlight to energize electrons and form an electric current.[32] Wind resources and most hydro-powered systems function by using wind and water respectively to rotate turbines with affixed electromagnets to generate an electric current. Geothermal, though not a focus in the proposed DoD Climate Act, is another renewable energy resource available to the Department of Defense. In order to test a transition to these renewable energy sources, in 2010, the Army's Net Zero Initiative launched 17 pilot installations meant to model sustainable paths to operational energy security.[33] Additionally, the DoD is installing solar systems in other locations with abundant solar radiation available; however more investment is needed in order to achieve a fully net zero energy infrastructure by 2030.

Microgrids

One element of many of the Army's net zero pilot installations, and a focus of the proposed DoD Climate Act, is the incorporation of microgrid systems. A microgrid is an electric grid that generates energy locally and operates and distributes power independently of a larger utility grid. Microgrids are typically characterized as being self-reliant and small but scalable. This self-reliance comes from the fact that microgrids have the ability to become standalone systems, "islanding" from the main utility grid. Microgrids produce energy on-site, which eliminates the need to transport electrical currents or fuel over long distances. This both reduces energy consumption *and* minimizes the potential for energy loss during transmission. Installing microgrid systems can grant DoD installation energy independence and control of its energy sourcing. In the event of a power outage, microgrids can also recover quickly, improving resilience against extreme weather events or other potential forms of interference.

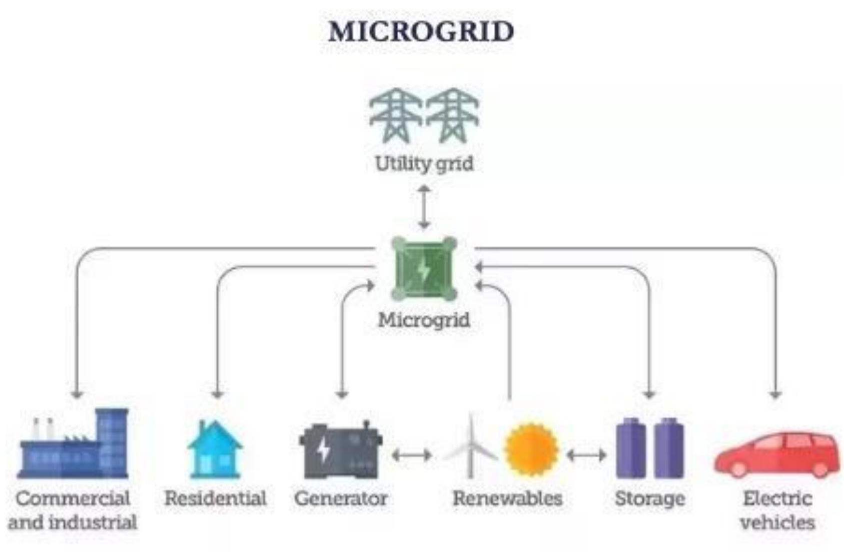

Figure 4: A microgrid illustrated [34]

The independence of microgrids is also beneficial to the DoD in its pursuit of net zero energy, because microgrids allow the DoD to more directly control the means of energy production. Though commercial utility networks have been slow to fully adopt renewable energy sources, the DoD could move forward on its own by integrating solar or wind energy resources into microgrid systems. In addition, the proposed DoD Climate Act allows for the use of hybrid microgrid systems, which use a combination of renewable sources and fossil fuel generators as backup, to provide a transition mechanism while the DoD is investing in development of more reliable renewable technology and supportive energy storage systems. Currently over 30 DoD installations have standalone microgrids or hybrid microgrid systems that connect to the main utility grid or use a mix of conventional and renewable energy sources.[35] In the past, microgrids were mostly diesel-powered and were used as a backup system when a power outage occurred; but now, microgrids are becoming more renewable, reliable, and resilient with technological innovation. The net zero initiative at Fort Carson in Colorado is an example of this, where a hybrid microgrid has been installed including a one megawatt solar PV array, three diesel generators and a 4.5 megawatt battery storage system.[36] This microgrid has been able to increase energy efficiency and maintain an adequate power supply for the site, and serves as an intermediary mechanism while the base moves towards a goal of net zero waste, water, and energy usage. Eventually the site will incorporate additional solar, wind, heat pumps, and biofuels into its microgrid.

Challenges in Renewable Energy Adoption

As the DoD continues to transition toward renewable energy use, there are significant challenges to be addressed from ecological, economic, and practical perspectives. These vary in complexity but merit acknowledgement, and many will require investment in energy efficiency and renewable energy technologies in order to mitigate negative impacts.

Although solar, wind and hydropower are hailed for their low GHG emissions, these forms of renewable energy often have unintended ecological consequences. For example, solar energy generation necessitates a large amount of land. In solar efficient locations, life-cycle land use might be less than that required for a coal power plant; however, in populated areas solar energy requires valuable land resources.[37] To counteract this, Fort Bliss in Texas installed long lines of solar panels on the rooftops of parking lots, a creative solution that occupies an otherwise empty space.[38] Similarly, while wind turbines are responsible for a high number of avian and bat deaths each year this must be contextualized in comparison with fossil fuel plants, which have been found to kill more than ten times as many birds per gigawatt-hour of electricity produced.[39] Still, investment in technologies to reduce the danger to wildlife should be considered in order to mitigate these impacts.

Hydropower facilities pose the most significant environmental issues, as artificially damming water sources can fragment local ecosystems and prevent the growth of wildlife and vegetation which are natural means of carbon sequestration. Newer hydropower facilities, or those adjusted to minimize damage, can have a near-zero impact, but because of these issues, they may have worse ecological externalities than the coal and natural gas plants such hydropower facilities would replace. Therefore, careful consideration of location and technology is important when planning new renewable energy projects. That said, most of these ecological consequences are relatively small when compared to the positive environmental impact of renewable energy sources. Indeed, ongoing scientific innovation is providing a pathway to reduce these adverse effects.

Alongside ecological impacts, the intermittent nature of solar and wind energy production poses another challenge to achieving net zero energy, from both a practical and fiscal standpoint. Intermittency can mean limited reliability, and systems supported solely by standalone wind or solar may risk outages if renewable production fails to keep up with demand at all hours of the day. Battery storage can help address this issue, and the steep decline in the cost of utility-scale batteries in the last decade makes them a feasible energy storage mechanism for renewable energy microgrids.[40] However, current battery storage technology is still relatively expensive and also carries environmental costs. Battery manufacturing can also be water intensive and includes the use of toxic chemicals, and it often relies on cobalt mining, an industry that is notorious for human rights and labor abuses.[41] The DoD, therefore, must continue to support funding for research and development of new battery technology to reduce the monetary and environmental cost of batteries. Furthermore, a significant military investment in energy storage technology is needed to improve the current capacity of batteries for the efficient implementation of large-scale renewable energy projects.

Without substantial energy storage, utilities need to be ready and able to meet demand as it fluctuates throughout a given day. The effectiveness of solar PV and wind power depends on their ability to respond to peak energy demands *and* align production with the period in which most energy is being drawn from the electrical grid (usually in the evening). If the peak demand period occurs at a time of day when solar panels are less efficient in capturing energy from the sun, more solar panels will be required to reconcile the difference. For example, if five megawatts of energy are demanded between the hours of 6-7 pm, and a solar array is only 50% efficient during that time, the array would need to include panels rated for a maximum production capacity of ten megawatts to cover the demand. Otherwise, any energy that can't be produced in the moment would need to be drawn from battery storage or from other energy sources. This means that, to ensure non-operational sources can always meet demand, the DoD may have to intentionally over-build renewable energy resources.

Peak load balancing, or flattening the demand curve throughout the day, can help reduce the strain on energy resources and the need for batteries or over-building, but it requires behavioral change on the part of energy consumers. Energy companies can flatten this curve by charging more for energy during peak periods or otherwise encouraging individuals to spread out their electricity use throughout the day. For example, the peak demand period tends to occur from 6-7 pm because consumers are turning on lights, using heating or air conditioning, watching TV, cooking, and doing laundry during these hours. If consumers can be convinced to shift some of these activities to a different time of day, it will reduce the intensity of the peak. While changing consumer behavior can be difficult, it provides a very cost-effective means to reduce energy production without reducing total consumption. By implementing programs to encourage these changes, the DoD can help overcome a significant barrier towards achieving net zero energy.

Changing the Market

To support the development and adoption of renewable energy, the proposed DoD Climate Act also requires climate-conscious spending. The DoD's efforts must reduce the amount of GHGs it emits both directly (through scope one emissions) and indirectly emissions (through scope three emissions).[42] Scope one emissions will largely be addressed through climate-conscious budgeting that directs money spent on renewable energy innovation and utilization. Climate-conscious contracting will complement these efforts by addressing scope three emissions, and has the potential to shift technology, R&D, and defense markets toward renewable energy adoption.

The DoD does not operate in isolation; rather, it is supported by a vast network of contractors and large companies in the defense and technology sectors. In 2019, the DoD awarded $402 billion in contracts—nearly 60% of their annual budget and approximately 30% of the entire federal government budget that year.[43] The climate-conscious contracting outlined in the proposed DoD Climate Act requires contractors to conduct physical and transition risk assessment of their own operations and report their findings to the DoD as part of the bidding process. Contractors must also have an active and robust risk management plan to address any identified climate risks. In addition, contractors must demonstrate active climate change mitigation efforts. Each contract proposal must include an estimate of the associated GHG emissions from the work requested. Notably, contractors must also prove that 100% of their energy consumption for the entirety of their operations is renewably sourced. Should this not be the case, a 1% fee of the total contract sum will be levied. While a small percentage, even 1% of $402 billion is a huge nominal sum, and when combined with the direct investment of the DoD in energy efficiency and renewable energy, the levied fee will make an impact on the larger U.S. market.

The DoD's demand for energy storage will significantly expand the market, quintupling the current domestic demand for large-scale storage; indeed the domestic market for large-scale storage totaled 107 MW in 2017.[44] Historically, the DoD has funded advanced technological innovation, including development of the nuclear reactor, the gas turbine, and the solar photovoltaic (PV) cell.[45] Its investment in advanced technology is a force multiplier that will continue to foster energy innovation.[46] Should the DoD be successful in furthering net zero energy technologies, storage, and distribution, it would furnish the U.S. with viable renewable energy capacity.

Interagency Cooperation

To oversee the implementation of the proposed DoD Climate Act, the Secretary of Defense is required to appoint an Assistant Secretary of Defense of Energy and Climate Resiliency to each branch of the military. To properly address climate change, the Secretary of Defense will need to set a long-term direction and centralized coordination, as well as accounting for the action of each branch of the military. Further recommendations for the implementation of the proposed DoD Climate Act will be discussed in subsequent analyses.

THE SCIENTIFIC MEASUREMENTS OF SUCCESS

In order to determine and measure the success of the proposed DoD Climate Act in combating climate change, it is imperative to discuss how it can be measured scientifically. Accordingly, this report examines both physical and economic metrics of success.

Physical Metrics of Success

Physical success of the proposed DoD Climate Act will be defined as:

1. Increasing military infrastructure security against the physical risks of climate change.
2. Increasing research and development on energy resiliency, energy storage, and (hybrid) microgrids.
3. Achieving net zero energy at non-operational sites by December 31, 2029.

Incorporating climate resiliency into existing military strategy will be the first indicator of physical success of the proposed DoD Climate Act. Climate resiliency occurs when the DoD has adequately adapted to the changing environment and has maintained essential functions during climate disruptions. Scientists are certain climate disruptions will increase in severity and frequency; thus the DoD must better manage its climate change risks. Climate resiliency can be measured as fewer outage events and fewer mission-essential operational disruptions. In 2018, there were 162 outages at DoD installations caused by climate-related events lasting over 8 hours each.[47] Risk assessment will be a critical component to address these issues. The successful development of a Climate

Vulnerability and Risk Assessment Tool will allow the DoD to uniformly assess the risks of climate change at installations. These climate change vulnerabilities to military installations must be compiled, prioritized and reported to the congressional defense committees. An annual report documenting the effects of climate change on the DoD installations will also be considered an indicator of success.

The DoD has taken the issue of climate change seriously for the past four administrations. In nearly every year since 1993, energy conservation projects have been included in the DoD's budget, yet the DoD remains the world's largest single consumer of oil. In addition to 2019's *Report on Effects of a Changing Climate to the Department of Defense,* the DoD has worked in conjunction with both the House and Senate Armed Services Committees.[48] Despite multiple efforts, the DoD has failed to adequately prepare to address these increasing threats. As it is, more than 1,700 military installations may be affected by sea level rise.[49] As shown in Figure 5 below, the 2018 *Climate-Related Risk to DoD Infrastructure Initial Vulnerability Assessment Survey Report* identified sites across the country that indicated effects from multiple vulnerability areas (flooding, extreme temperature, wind, drought, wildfire).[50] To successfully address the issue of climate change there must be explicit long-term direction, accountability, and centralized coordination from the Secretary of Defense.

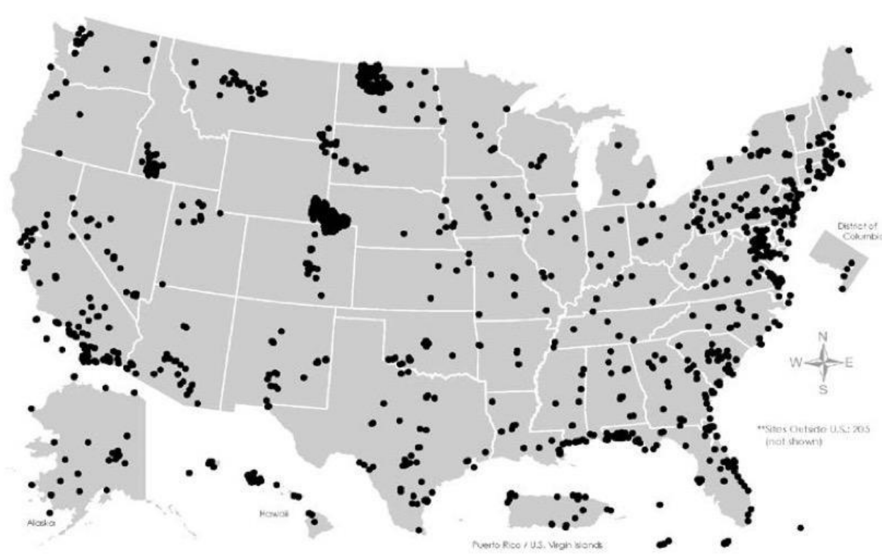

Figure 5: DoD sites with multiple climate vulnerabilities [51]

A commitment by the DoD to continue to research and further develop renewable energy technology will spur innovation and increase energy resiliency. The allocation of funds towards the research, development, and implementation of renewable energy technology will therefore be considered an indicator of the success of the proposed DoD Climate Act. Technological innovation will improve the viability of microgrids and allow for wide-scale adoption of renewable energy throughout military installations. Energy resiliency improves energy reliability, resulting in fewer utility outages, while increasing energy efficiency and storage. On the one hand, energy efficiency decreases the amount of energy required to power DoD installations, while on the other, energy storage increases the capacity of on-site batteries to store energy for DoD installations.

Net zero energy is the primary indicator of physical success of the proposed DoD Climate Act. By December 31, 2029, the DoD must locally produce as much renewable energy as is consumed at non-operational installations. To determine whether net zero energy has been achieved, energy production and energy consumption must be measured at each non-operational installation. Success of the proposed DoD Climate Act will ultimately occur when the amount of renewable energy produced at non-operational installations is equal to the amount of energy that such installations consume from non-renewable sources. GHG emissions from on-site energy consumption of non-renewable sources should be measured at each non-operational installation and be ranked according to megatons of carbon dioxide emitted. The proposed DoD Climate Act requires an annual ranking of military installations that emit the most carbon. As shown, successful achievement of net zero energy by non-operational sources will decrease the overall environmental footprint of the DoD.

Economic Metrics of Success

The economic success of the proposed DoD Climate Act will be defined as:

1. Preventing financial damages associated with climate disruptions at DoD installations.
2. Climate-conscious budgeting: decreasing fossil fuel spending and increasing renewable energy spending.
3. Climate-conscious contracting: hiring defense contractors with aggregate net zero energy.

The successful incorporation of climate resiliency into existing military strategy will result in less money spent repairing damages to installations caused by future climate events, itself a major economic indicator of victory. Decreased fossil fuel spending and increased climate-conscious spending will also indicate success of the proposed DoD Climate Act. In the future, a higher percentage of the military budget should be allocated to climate initiatives and renewable energy. In 2018, renewable energy comprised only 2% of total DoD installation energy costs.[52] Historically, installation energy represents roughly 30% of DoD total energy.[53] By definition, all energy used to power fixed military sites and infrastructure, as well as vehicles that do not support combat operations, is considered installation energy.[54] Successful climate-conscious spending would also increase the hiring of DoD contractors that utilize 100% renewable energy.

Another metric to track the progress of climate-conscious contracting will be the frequency with which fees to combat climate change are levied on DoD contracts for the procurement of property or services. The fees, as mentioned earlier, will be equal to 1% of the value of the contract and will be applied if the contractor cannot verifiably produce as much renewable energy as it consumes. Hence, the total amount of fees that are paid by contractors to the DoD can also be used to track the progress of climate-conscious contracting.

Feasibility of Measurement Techniques

The measurement techniques in the proposed DoD Climate Act (Tables 1 and 2) are already implemented in the scientific community. In all, there are five primary metrics of measurement: days with operational interruptions, megawatt hours of energy consumed and produced, megatons of CO_2 emitted, and dollars spent. It is important to note that some methods of measurement are more straightforward than others. In other words, should the proposed DoD Climate Act be enacted, achieving 100% net zero energy at non-operational installations within the decade is a clear indicator to benchmark the DoD's progress. Increased climate resiliency at DoD installations, however, requires a more nuanced analysis as climate change will continue to pose risks that are today unseen by the military. Since climate-related threats to military installations and operations will increase and continue to evolve as our planet warms, a long-term analysis should be conducted in order to properly assess the DoD's management of climate risks. Similarly, tracking the DoD's budgetary expenditures on fossil fuels and renewable energy is a straightforward metric, but the societal impact resulting from the DoD's investment in renewable energy technologies and divestment from fossil fuels can only be determined years after implementation. It is clear that society has benefited from the innovation spurred from technological investments made in the name of military necessity. Nonetheless, determining the effect of military dollars in moving the renewable energy market will be more difficult to quantify.

CONCLUSION

Our research highlights the importance of enhancing the readiness of the DoD to respond to the known and unknown threats posed by climate change. It's always good military policy to prepare for the worst, but in this case investments towards climate resiliency are a matter of preparing for the inevitable. The United Nations has declared climate change the defining problem of our time as humanity faces a direct, existential threat. Adaptations are currently available and should be implemented at DoD installations that are currently threatened or will be in the future. The proposed DoD Climate Act will assist the DoD in mitigating its climate risks while also reducing its role in climate change through GHG emissions. The DoD has begun on this path but must accelerate its progress and take prudent steps to improve resilience and reduce its carbon footprint. It is essential that the DoD first establishes functional climate vulnerability and risk management tools to further assess the dangers posed by the current climate crisis. The DoD must also strive for energy efficiency and set clear and enforceable targets to reduce energy use. At the same time, the DoD must capitalize on the potential of existing technologies to secure energy resources through renewable means, and thus achieve energy resiliency in preparation for the challenges relating to climate change. By the end of this decade, non-operational sources of the DoD should be capable of locally producing as much energy as is consumed through renewable energy sources.

The transition to net zero energy consumption is feasible for the DoD. Net zero energy will be achieved through the allocation of resources to the research and development of electric grid technology and the implementation of renewable energy projects at DoD installations. Our country has an illustrious history of energy and technological innovation impelled by investments made in the name of military necessity. The proposed DoD Climate Act will be considered successful when the DoD demonstrates increased readiness to respond to climate threats and, most importantly, attains 100% net zero energy usage by 2030.

Appendix

Table 1. Scientific indicators of success, summary table of physical outcomes defined by the proposed DoD Climate Act, methods and metrics of measurement.

Definition of Success	Outcome	Scientific Indicator of Success	Method of Measurement	Metric of Measurement
PHYSICAL	Manage the risk of climate change	Increased climate resiliency at DoD installations	Fewer operational interruptions (communication, access) due to climate events	Number of days with operational interruptions
	Net zero energy	100% net zero energy at non-operational DoD installations	Total energy **consumption** at non-operational DoD installations	Megawatts-hour (MWh)
			Total renewable energy **production** at non-operational DoD installations	MWh
		Net zero carbon emissions	Neutralized carbon emissions, CO_2 = carbon offset	Megatons (Mt) CO_2
	Expanded R&D	Increased energy efficiency	The percent of energy lost	MWh
		Increased energy storage	Increased on-site battery storage capacity	MWh
		Increased energy reliability	Fewer operational interruptions due to energy outages	Number of days with operational interruptions
		Increased adoption of solar, wind, hydropower	Total renewable energy **production** at non-operational DoD installations	MWh

Table 2. Scientific indicators of success, summary table of economic outcomes defined by the proposed DoD Climate Act, methods and metrics of measurement.

Definition of Success	Outcome	Scientific Indicator of Success	Method of Measurement	Metric of Measurement
ECONOMIC	Manage the risk of climate change	Increased climate resiliency at DoD installations	Less money spent on infrastructure damages at DoD installations	$
	Change the markets	Increased climate-conscious spending	Total fossil fuel spending as a percentage of total energy spending	$
			Total renewable energy spending as a percentage of total energy spending	$
			Total spending on green infrastructure	$
		Increased climate-conscious contracting	Energy efficient contracts as a percentage of total contracts	$

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