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DELIVERING A SUSTAINABLE TOMORROW:
THE U.S. MILITARY'S ROLE IN THE FUTURE OF GLOBAL CLIMATE CHANGE

by

Theodore J. Shanks, BA, MA

Lt Col, USAF

National Defense Fellow. Watson Institute for International and Public Affairs

Brown University

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Advisors:
Professor David A. Polatty, CAPT, USNR
Watson Institute, Brown University

Ms. Mona D. Taylor
Air University

Maxwell Air Force Base, Alabama

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PREFACE AND ACKNOWLEDGEMENTS

When I began this research, I did so with the intent of highlighting an issue I knew to be critical, but one I felt was largely underappreciated in my community. The effects of climate change around the world have the full attention of the scientific community but have been manipulated into a political hot topic over the last several decades; more so now than ever before. Regardless of political rhetoric, there is clear, quantifiable, and data-verified evidence of climate change and its connection to America's national security interests. These links should—in theory—rise above political acrimony. With this in mind, this research seeks to illustrate urgent national and public policy recommendations which should entertain support from across the political spectrum.

As a result, this research does not attempt to add to the already-significant amount of research affirming human effects on climate change, although it does briefly introduce this research and reference it throughout. Instead, it focuses on the realized and probable threats to global stability and security posed by climate change, how the U.S. Department of Defense has contributed to the advancement of climate change, and what can be done to prepare for—and prevent future—climate-based security threats.

While conducting my research, I was pleased to find open, candid, and engaged discussion of Climate Security from both academia and defense institutions alike. Both communities were willing to acknowledge concerns or threats, and to entertain potential solutions both now and in the future. Several public engagements with this research, however, highlighted significantly more misinformation and friction, primarily as a result of political intrusions into this scientific field of discourse.

The research contained herein aims to be an objective, data-based, and apolitical attempt to define climate change-based threats and recommend ways to mitigate or halt these effects. Although several recommendations will require political support to become a reality, they are recommendations that should garner universal support, as they are in direct alignment with our Nation's stated goals and national security objectives.

I would like to acknowledge significant guidance and assistance from Ms. Dee Taylor from Air University, as I shaped my research and subsequent thesis. Additionally, I cannot understate the support, guidance, and resources provided me by the Watson Institute for International and Public Affairs, its faculty, staff, and students. Most especially, the guidance of Dr. Ed Steinfeld, Director of the Watson Institute, Professor (CAPT, USNR) Dave Polatty, Director of the Watson Military Fellows Program, and Professor Alice Plane and Dr. Alexander Gard-Murray of Brown University, for their thought, discussion, and continued engagement. I would also like to acknowledge the research and guidance of Dr. Neta Crawford of Boston University and Brown University's "*Costs of War Project*," whose research provided vital insight into the effect the Department of Defense—and that of global conflict writ large—has on global climate change. Finally, I owe the greatest thanks and acknowledgement to my incredible wife, Laura, and to my children, Penny and Ellie, for their patience and assistance as partners in this endeavor as supporters of my research, keen editors, diligent fact-checkers, and joke-telling morale boosters.

ABSTRACT

The nature of war does not change. This Clausewitzian principle, ground into the minds of even the youngest military scholars, has influenced generations of strategic minds. While no doubt valid, this axiom paradoxically tends to stifle innovative technologies and concepts, hoodwinking young military planners into believing innovation has little place in warfare. *If war never changes, why evolve?* However, while war's *nature* is indeed constant, war's *character* undoubtedly evolves. The U.S. Department of Defense, as well as the various federally funded think-tanks and academic institutions around the nation, spend considerable money, resources, and effort to uncover new and emerging threats to American security and devise ways to prevent, mitigate, or eliminate those threats. One threat, although clearly identified for nearly a century, remains conspicuously by the wayside: global climate change.

Human-caused climate change has been scientifically well-established for decades, and the security threats it poses—both natural and man-made—are readily apparent. Rising levels of greenhouse gasses (GHGs), are raising the globe's surface and sea temperatures, increasing ocean levels and salinity, and are affecting the planet's solar reflectivity, or albedo, primarily due to variations in global sea and land ice.

These effects are—and will continue to have—serious, significant effects on our planet. These "symptoms" of climate change and planetary warming manifest themselves in destructive, dangerous, and destabilizing ways. Since the pre-industrial age, when the world began slow but steady increases in the emission of man-made greenhouse gasses, data shows clear rises in the length, duration, and energy of cyclonic activity, the creation of longer and deadlier temperature extremes, and climate change-based conflict as a result of resource scarcity and displacement.

In its October 2021 Climate Risk Analysis, the U.S. Department of Defense minced no words in its assessment of climate change as a national security risk: "Climate change is reshaping the geostrategic, operational, and tactical environments with significant implications for U.S. national security and defense."[1] Since its prominent inclusion in the 2015 National Security Strategy, the Department of Defense has worked steadily to mitigate the effects of climate change and prepare for its future ramifications.

Less prominent in the DoD's efforts, however, is addressing how it could meaningfully prevent future climate change. The DoD is the single largest institutional emitter of CO_2 in the world and has a moral obligation to do better.[2] Several initiatives, seeking alternative or sustainable fuels, increasing clean energy at installations, and adopting net-zero practices, indicate the DoD's seriousness in addressing the matter. Unfortunately, this is realized through a complex series of unfocused, service-specific efforts.

This research concludes with several recommendations for future action, intended to reduce the DoD's carbon footprint dramatically over the next thirty years. By pursuing alternative aviation fuels, developing and fielding carbon-neutral or carbon-free vehicles and equipment, and deeply investing in and developing carbon capture and transformation technology, the DoD can viably reach net-zero operations before the end of the 21st Century.

That said, even if the DoD reached net-zero today, it wouldn't appreciatively affect the planet's increasingly urgent climate crisis. Where the DoD can make a difference globally, is by coordinating a focused, results-driven nationwide effort that joins military resources and

[1] U.S. Department of Defense, Office of the Undersecretary for Policy (Strategy, Plans, and Capabilities), "2021 Climate Risk Analysis," (Washington, DC: DoD Press), 2021, 2.
[2] Neta Crawford, "Pentagon Fuel Use, Climate Change, and the Costs of War," (Providence, RI: Brown University, 2019), 2.

guidance with academic and scientific expertise to develop technologies and influence industry—making them commercially viable. With this end-state in mind, this research's final recommendation is the establishment of a "Manhattan Project for Climate Security," giving focus, resources, and national-level authority to an increasingly hazardous threat to our national security.

Chapter I

Introduction to Global Climate Change and Its Effects

"We will respond to the threat of climate change, knowing that the failure to do so would betray our children and future generations..."

-President Barack Obama, 2nd Inaugural Address[3]

The science behind the advance of global climate change and mankind's role in accelerating its effects is well-founded. Despite the recent political debate surrounding climate change and its causes, the scientific community has been investigating mankind's effect on Earth's climate for nearly two centuries and has reached widespread consensus on the certainty of human-caused climate change and its effects. One of the most recent and powerful illustrations of this consensus was authored by Krista Myers, et. al. in her 2021 work, "Consensus Revisited: Quantifying scientific agreement on climate change and climate expertise among Earth scientists 10 years later." "Consensus Revisited," surveyed thousands of academic and science professionals from around the world. They found that this group of professionals—with varying levels of experience—were 91-100% in agreement that climate change existed, and that human activity was a key cause of that phenomenon. Furthermore, they concluded that of those respondents deemed "highly experienced" in climate or planetary science were 100% in agreement with those conclusions.[4] In short, the world's most dedicated experts in the field of climatology are largely in agreement on human-caused climate change and its effects; but this consensus is hardly new.

As early as 1824, planetary climate researchers like Joseph Fourier, Eunice Foote, and John Tyndall had firmly established the existence of a planetary "blanket" surrounding Earth and resulted in

[3] Barack Obama, "Inaugural Address by President Barack Obama," (Washington, DC: Office of the Press Secretary, 2013).
[4] Krista Myers, et. al., "Consensus Revisited: Quantifying scientific agreement on climate change and climate expertise among Earth scientists 10 years later," *Journal of the Institute of Physics*, Volume 17, Number 10, 20 October 2021, 4.

the natural balanced heating of its surface and oceans. The collection of atmospheric gasses created a "greenhouse effect" on the earth. The term "Greenhouse Gas (GHG)" is now often used to describe the gasses which create the "blanket" over our planet. Although largely a natural occurrence, these early researchers also concluded that Earth's atmospheric blanket could be—and was indeed being—affected by human-generated emissions.[5] Over the course of the next century, additional evidence mounted, reinforcing the effect man-made GHGs were having on Earth's climatological dynamics.

In 1957, oceanographer Roger Revelle and chemist Hans Suess published their research debunking a popular theory at the time which claimed Earth's vast oceans would absorb CO_2 faster than humans could release it into the atmosphere. Partially funded by the DoD, their research also concluded that atmospheric CO_2 was, in fact, largely contributing to sea and surface temperature increases, and that human activity played a key role in the release of greenhouse gasses.[6]

The decades that followed saw increasing evidence of the links between climate change and human activity, and the subject quickly garnered the interests of the national security community. In 1990, Terry Kelly, a civilian researcher from the U.S. Naval War College, published research detailing the national security concerns of climate change, with particular emphasis on naval operations. Even though Kelly clearly believed in the urgency of his argument, his still hesitated to be conclusive, adding a remarkably un-scientific (even at the time) caveat: "Although no conclusive evidence exists to prove global warming as a fact, a large body of circumstantial evidence and expert opinion does exist supporting the existence

[5] National Aeronautical and Space Administration (NASA), "Climate Change: How do we Know?" 2022, https://climate.nasa.gov/evidence/.
[6] American Institute of Physics, "The Discovery of Global Warming – Roger Revelle's Discovery," August 2021, https://history.aip.org/climate/Revelle.htm.

of the phenomena."[7] Despite this, Kelly goes on to describe—in remarkable detail—the considerable climate change threats to naval operations, planning, installations, and resources.

Luckily, the early 1990s saw significant technological and scientific advances which further reinforced human effects on climate. With this research came the firming of several effects of climate change. While these effects are nuanced and varied, there are several which play prominent roles in how the planet's climate is changing and its subsequent effect on America's national security interests domestically and abroad. Before reviewing those specific effects, however, it is important to review the primary science behind GHGs and resultant climate change.

Greenhouse Gasses (GHGs) and Global Warming

As briefly reviewed above, the scientific understanding of GHGs dates to the early 19th Century, and has been further researched, verified, and reviewed since. Built upon the earlier research of Foote, Fourier, and Tyndall some decades prior, the research of Irish physicist John Tyndall is also recognized as a key player in cementing the role of GHGs in the world's heating. His 1859 series of papers, along with thousands of more research efforts in the decades prior and the ones that would follow, confirm that GHGs, consisting primarily of Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), and a variety of fluorinated gasses, were the primary players in the "planetary blanket."[8] CO_2 accounts for the largest share of atmospheric GHGs (approximately 80%), and Methane approximately 10%.

Human activity is largely responsible for the significant increases in atmospheric CO_2 and CH_4 over the last century and has resulted in the significant planetary heating since the industrial age of the mid-19th Century. Increases in atmospheric CO_2 over the last century is primarily a result of increased

[7] Terry Kelly, "Global Climate Change Implications for the United States Navy," (Newport, RI: US Naval War College, 1990), ii.
[8] United States Environmental Protection Agency, "Overview of Greenhouse Gasses," Greenhouse Gas Emissions, April 2022, https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

burning of fossil fuels—primarily oil, gas, and coal—via industrial practices. The significant rise in atmospheric CH_4 is primarily a product of widespread livestock, agricultural, fossil fuel extraction/production, and landfill off-gassing practices.[9]

The effect of increased human induced GHG release has resulted in increases in global average air temperatures, average sea temperatures, average sea levels, ocean salinity, and has resulted in planetary albedo, leading to dramatic shifts in the planet's climatological and meteorological patterns. Second only to China, the United States is the largest emitter of greenhouse gasses in the world.[10]

Rising Average Global Surface (Air) and Sea Temperature

The primary effect of increased atmospheric GHGs is planetary warming, which has an extraordinary effect on the planet's fragile climatological and meteorological systems. Since the beginning of the Industrial Age—which brought with it historic levels of human-created CO_2 emissions—the Earth's average air temperature has risen by more than 1°C, and average global sea temperatures by nearly 2°C. In addition to the effect higher temperatures have on land and sea ecosystems and biodiversity, the rising temperatures are shown to have significant impact on worldwide severe weather, making disaster-level weather events both more frequent and more powerful. Left unchecked, air temperature increases are expected to continue rising well above 3-4°C, leaving large regions of the globe uninhabitable or non-conducive to long-term habitation. Several models predict that warming trends alone will likely make portions of the planet nearly unlivable for up to 3 billion inhabitants.[11]

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[9] Natural Resources Defense Council, "Greenhouse Effect 101," NRDC Website, July 2019, https://www.nrdc.org/stories/greenhouse-effect-101.

[10] US Environmental Protection Agency, "Global Greenhouse Gas Emissions Data," Greenhouse Gas Emissions, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

[11] Chi Xu, et. al., "Future of the Human Climate Niche," Proceedings of the National Academy of Sciences (PNAS) Journal, Vol. 117, No. 21, May 2020, 11350. https://www.pnas.org/doi/full/10.1073/pnas.1910114117.

Visualizations of the global average land surface temperature (Figure 1) and sea temperature (Figure 2) illustrate the steady increase of global planetary warming over the last two centuries. Even when considering the technological limitations involved in the 19th Century (illustrated by the upper and lower "confidence limits" in Figure 1), a trend of exponential warming is clearly visible.

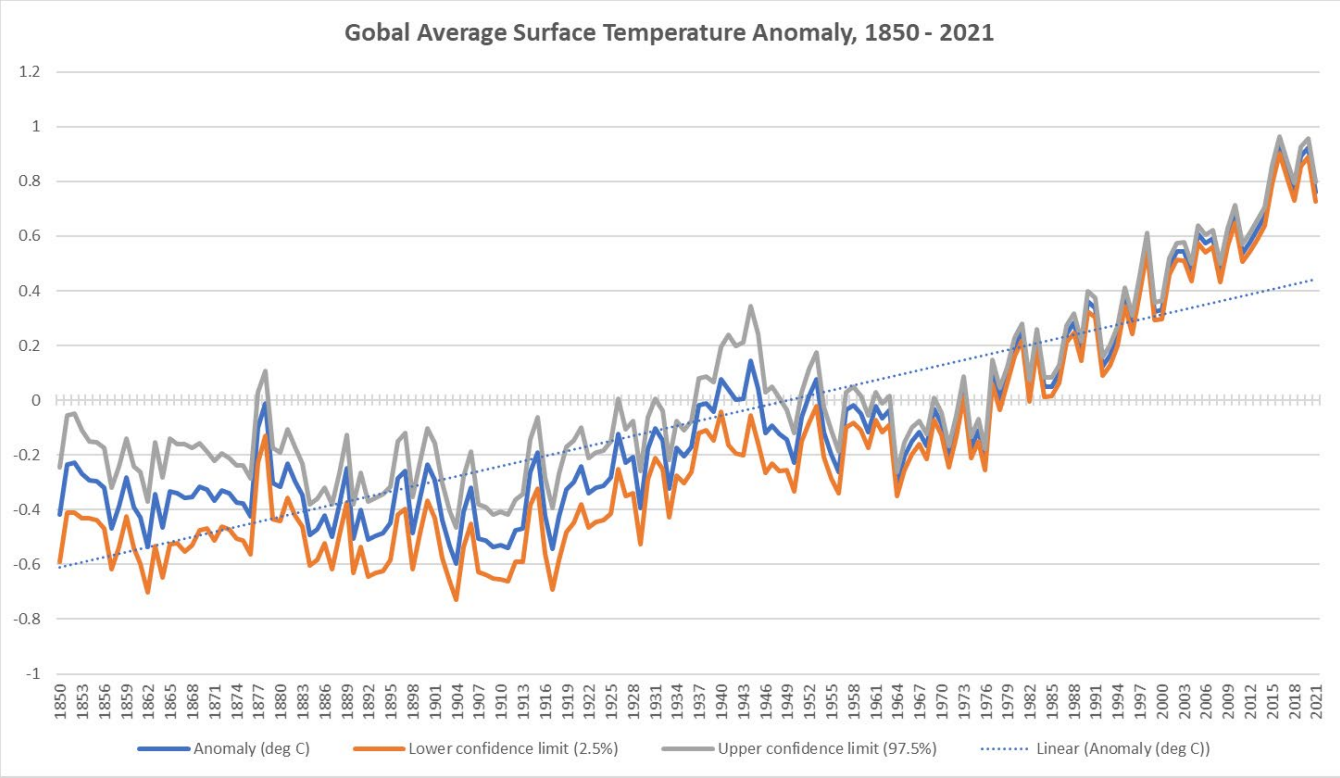

Figure 1- Global average surface temperatures sharply increased in the post-industrial era and are currently projected to continue rising through the 21st Century (Data Source: UK National Meteorological Office)

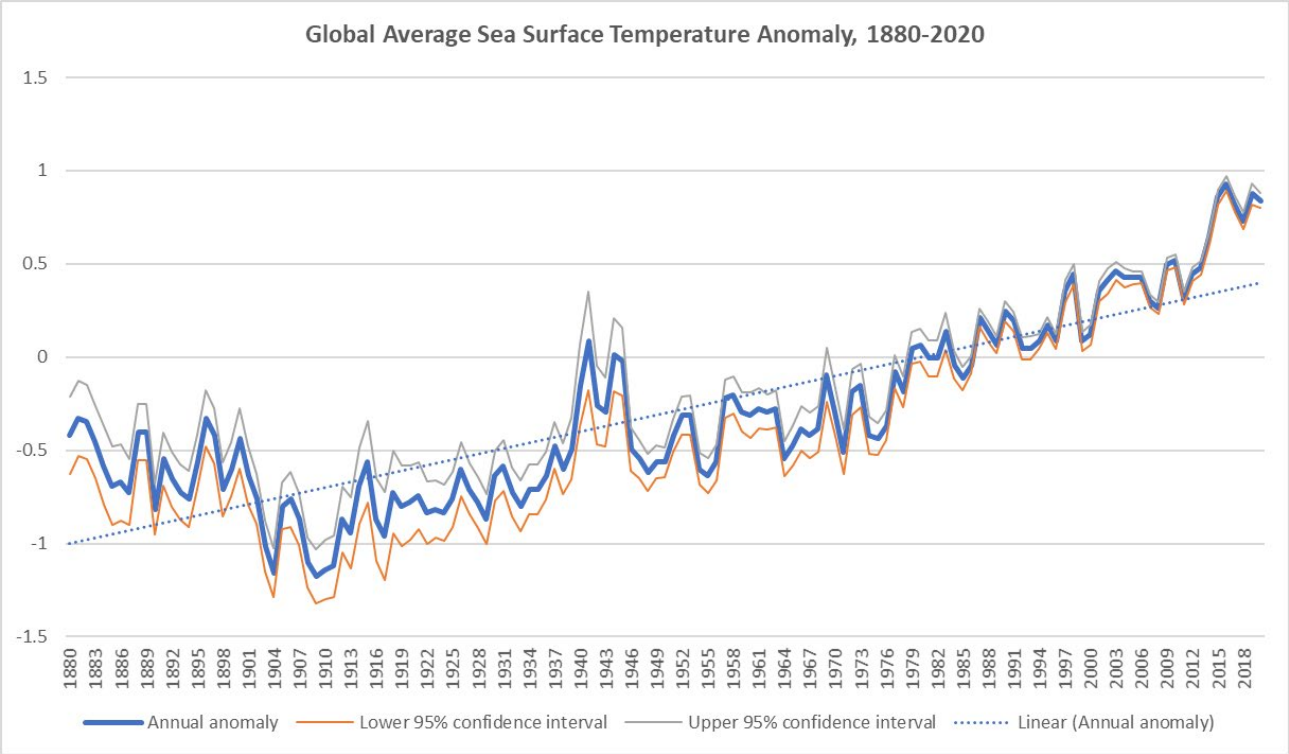

Figure 2 - Global average sea surface temperatures are expected to continue to rise through the 21st Century (Data Source: US EPA)

Rising Average Global Sea Levels

Much like the rise in air and oceanic surface temperatures, ocean levels are similarly rising both as a result of planetary ice melt and hydrological thermal expansion. While the global average of sea levels has risen more than 160mm over the last century, the rate of increase has exponentially risen over the last twenty years. It disproportionately affects certain global regions (Figure 3), specifically in the subtropical North Atlantic, South Atlantic, and Indian-South Pacific, but has potential to adversely affect operations and life in nearly any shoreline on the planet. [12] Sea level rise is of concern not just for the loss of arable land, but for the propensity of higher shorelines to amplify the effects of natural events like typhoons/hurricanes, floods, storm surges, and tsunamis.

Sea level rise is also amplifying the frequency and severity of extreme high tides, which is generally regarded as a high-tide event of two or more feet above the local daily average high-tide. As

[12] Thomas Frederikse, et. al., "The causes of sea-level rise since 1900," *Journal of Nature*, Vol. 548, 20 Aug 2020, 393.

with sea level rise, modeling predicts that extreme high tide events will become more common in nearly all worldwide coastal areas, rendering many low-lying areas nearly uninhabitable.[13]

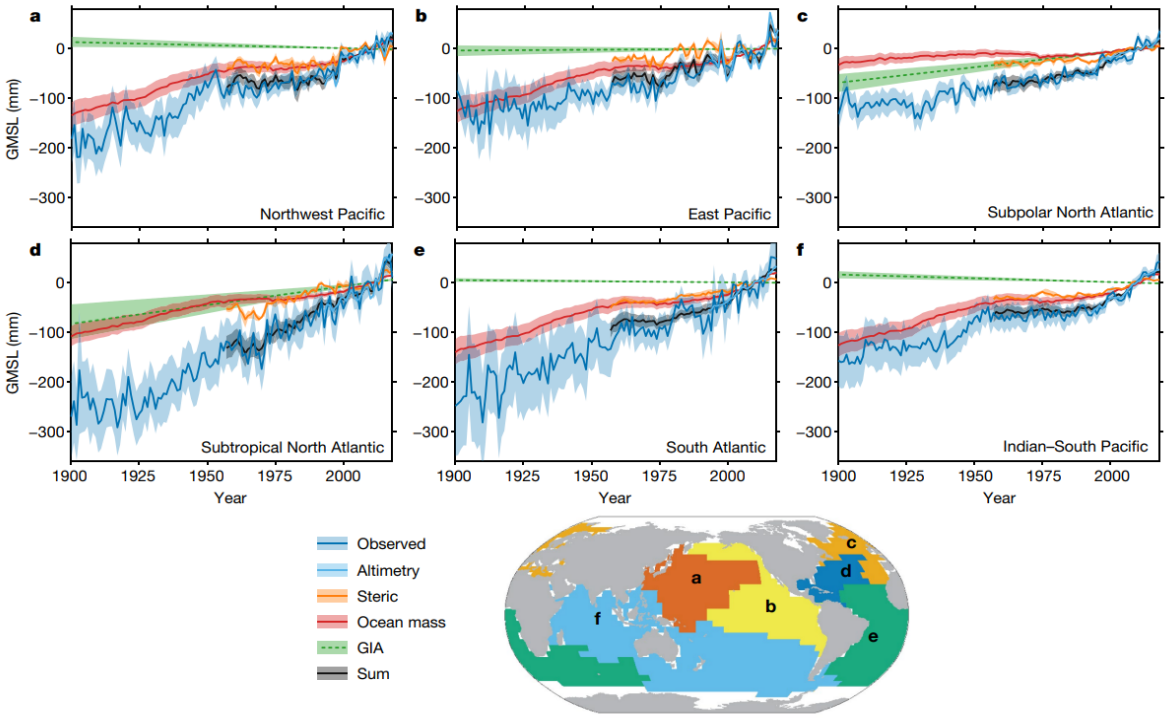

Figure 3 - Observed basin-mean sea level and contributing processes. (Frederikse, et. al., 2020)

Planetary Albedo

Polar and land-based ice melt is also perpetuating an effect known as planetary albedo, or the reflectivity of the earth's surface. A majority of Earth's surface with high albedo, or high reflectivity, is found in polar regions in the form of surface or sea ice. With global warming trends, the average trends of global sea and surface ice have reduced, and therefore reduced the albedo of the planet. As a result, the Earth's surface absorbs more solar energy in the form of heat, thus perpetuating the advance of global warming trends. While planetary albedo is not the leading cause of global warming, it does accelerate its effects and thus must also be considered.

[13] National Oceanic and Atmospheric Administration, "2019 State of U.S. High Tide Flooding with a 2020 Outlook," (Silver Spring, MD: NOAA Technical Press, 2019), NOAA Technical Report NOS Co-OPS-092, 12.

Chapter II

National Security Threats Posed by Climate Change

"Climate change touches most of what [the Department of Defense] does, and this threat will continue to have worsening implications for U.S. national security..."

-Secretary of Defense Lloyd Austin, 2021 DoD Climate Risk Analysis[14]

The national security threats generated by climatic shifts are vast, impacting an almost infinite combination of atmospheric, oceanographic, and socio-political arenas. Since its first inclusion in President George H.W. Bush's 1991 National Security Strategy (NSS), climate change has been highlighted as a stated national security threat in every Presidential NSS that followed it (with the notable exception of President Donald Trump's 2017 NSS, where climate change is mentioned only briefly as a goal for America to be a leader in "reducing traditional pollution, as well as greenhouse gasses, while expanding our economy.")[15] Almost a year into his term, President Joseph Biden took this guidance a step further and issued Executive Order #14507, directing all federal agencies to dramatically reduce their carbon footprint.[16]

Even before the release of this Executive Order #14507, and despite being granted the leverage therein to exempt itself from its contents, the DoD released its own Climate Adaptation Plan in September 2021 which was quickly followed by a Climate Risk Analysis in October 2021. Both documents succinctly describe the national security implications of climate change, and deliberately laid out goals,

[14] U.S. DoD, "2021 Climate Risk Analysis," 4.
[15] Office of the President of the United States, "National Security Strategy of the United States of America," (Washington, DC: National Archives Press, 2017), 22.
[16] Office of the President of the United States, "Executive Order on Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability," 8 December 2021, https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/.

policies, and recommendations to reduce the risks associated with a warming planet. In its Executive Summary, the 2021 Climate Risk Analysis states:

> *"Climate change is reshaping the geostrategic, operational, and tactical environments with significant implications for U.S. national security and defense. Increasing temperatures; changing precipitation patterns; and more frequent, intense, and unpredictable extreme weather conditions caused by climate change are exacerbating existing risks and creating new security challenges for U.S. interests."*[17]

The 2021 Climate Risk Analysis is very effective at identifying and communicating the security risks posed by climate change, and even goes so far as to link particular climate change effects with specific threats posed across multiple Geographic Combatant Commands (GCCs) (Figure 4).

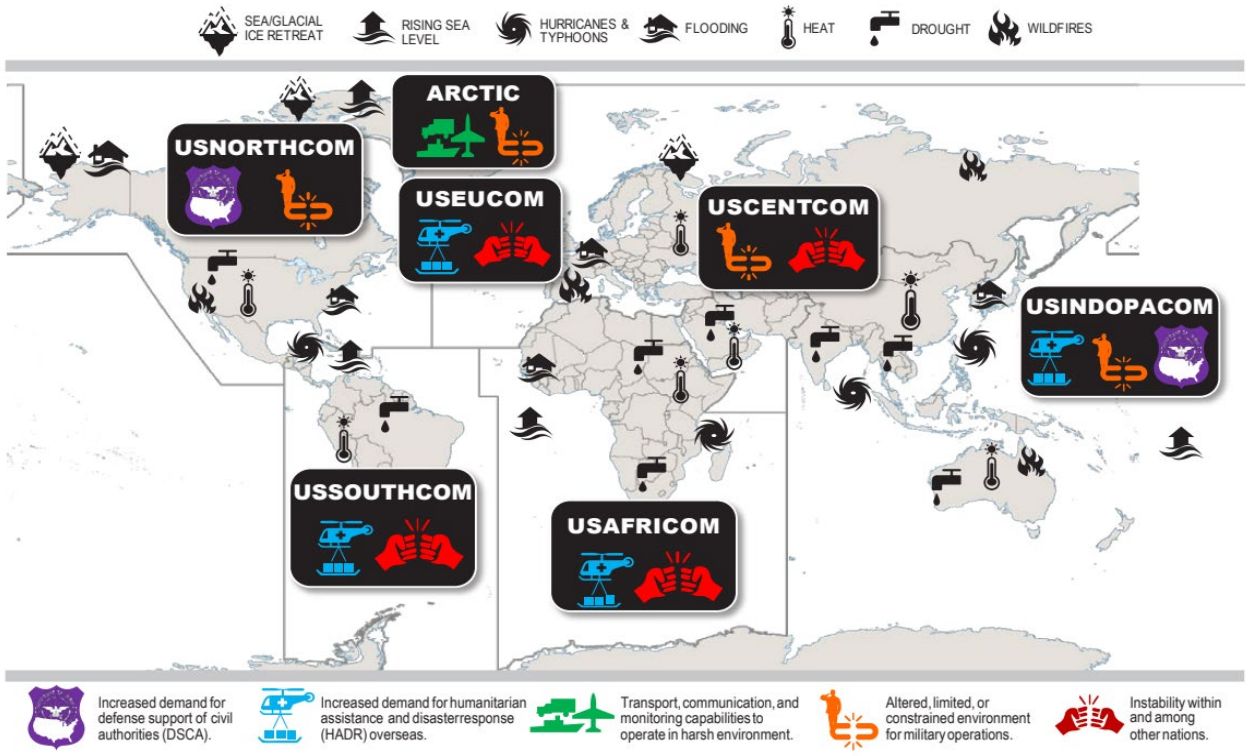

Figure 4 - Visualization of climate-based threats (Source: DoD 2021 Climate Risk Analysis)

[17] U.S. Department of Defense, "2021 Climate Risk Analysis," 10.

As described in the DoD Climate Risk Analysis and within several scientific products, there are several specific effects of global climate change which deserve to be highlighted as some of the most significant or immediate threats to American national security interests:

Arctic Melting and Arctic Ocean Freedom of Navigation

One of the most easily observable threats posed by climate change is the opening of a new area of operations, once considered largely unfit for regular, conventional military activity: the Arctic. Several studies have concluded that warming in the Arctic is leading to access and routes of commerce or militarization that were once considered rarely passable or impassable without specialized equipment or vessels (i.e., icebreaker vessels). Nathaniel Melia's groundbreaking 2016 research, "On Predicting the Opening of Arctic Sea Routes" combines historical observations of Arctic accessibility with climatological modeling to predict how accessible the Arctic is likely to become should global warming trends be left to continue.[18] His modeling suggests a vast majority of Arctic routes, accessible only to specialized icebreaking ships in 2015, will become accessible by conventional surface fleets—both civilian and military. (Figure 5)

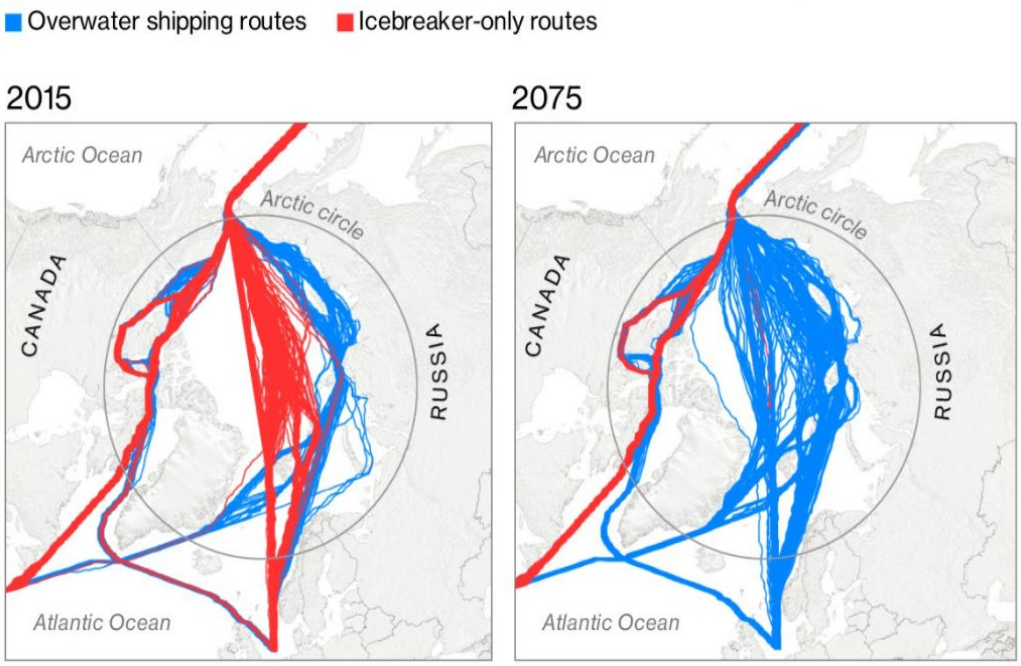

Figure 5 - Melia's predictive model of arctic sea routes, 2015 vs. 2075 (Source: Melia, 2015)

[18] Nathaniel Melia, "On Predicting the Opening of Arctic Sea Routes," (Reading, UK: University of Reading Press, 2016), 40.

Additionally, the last two decades have witnessed a remarkable buildup of Russian military capability in the Arctic circle. Nearly 25% of Russia's GDP originates in the Arctic, and the Russian Federation has created, refurbished, or expanded more than a dozen Arctic facilities in the last decade. [19] This includes new airfields, coastal early warning radars and air intercept systems, and reinforcing their already sizable air defense network in the region. Additionally, the Russian government has signaled its interest in controlling or regulating Arctic maritime traffic and operations, with particular interest in controlling several vast Arctic oil assets.[20]

Although they are not an Arctic nation, the Chinese government has also shown an interest in Arctic operations, particularly as a trade route in support of their "One Belt, One Road" initiative.[21] Combined with the surge in Russian interest in the area, the Arctic area of responsibility has the potential to destabilize or balance-shift power in the region.

Resource Scarcity and Climate Change-Induced Instability and Conflict

Another threat posed by climate change is its likelihood of driving instability and conflict worldwide, especially in areas already prone to economic and political strife. A remarkable study conducted at Stanford University in 2015 found a correlation between climate-change induced effects and how it quantifiably amplifies and creates global conflict. The intricate and scientifically grounded study in Stanford's *Economic Review* "Climate and Conflict," written by Marshall Burke, Solomon Hsiang, and Edward Miguel, found that among all climate change effects, average global surface temperature had the most disproportionate influence on conflict. Specifically, "Contemporaneous temperature has the largest

[19] Jeremy Hodges, Anna Shiryaevskaya & Dina Khrennikova. "Melting Ice in the Arctic Is Opening a New Energy Trade Route," *Bloomberg*, 28 Aug 2018, https://www.bloombergquint.com/business/arctic-ice-melt-opens-lng-energy-trade-route-near-north-pole.
[20] Department of the Air Force, "Department of the Air Force Arctic Strategy," (Washington, DC: DLA Press), 2022, 9.
[21] Nong Hong, "China's Interests in the Arctic: Opportunities & Challenges," Institute for China-America Studies (ICAS), 16 March 2018, https://chinaus-icas.org/research/chinas-interests-in-the-arctic-opportunities-challenges/#:~:text=China's%20interests%20range%20from%20participating,has%20been%20fairly%20low%2Dprofile.

average impact, with each 1°C rise in temperature increasing interpersonal conflict by 2.4% and intergroup conflict by 11.3%."[22] Given that most modeling suggests the world is on track for a 4-5°C increase in the next 50 years, this presents an alarming concern.

Additionally, agricultural and freshwater systems globally are being directly impacted by sea and surface temperature variations. The yields of crops and fisheries are highly sensitive to fluctuations in temperatures, and climate change is influencing change worldwide. In some cases, increased surface temperatures can, in some cases, actually benefit the agricultural industry.[23] Longer growing seasons and increased levels of atmospheric CO_2, for example, could potentially boost harvests. However, even these benefits are likely to be outweighed by other secondary concerns like larger, heartier damaging insects, and more frequent and more devastating natural events like flooding or drought. Unfortunately, most of the world's vital crops are unlikely to benefit from higher temperatures or longer growing seasons.

Several models suggest that some of the largest growers of the world's food—namely North and South America, Northern Europe, and many portions of Asia—will produce significantly smaller harvests by 2050 as a result of climate change. While wheat is most resistant to the effects of climate change, it won't be able to offset the predicted declines in corn (-24% decline), rice (-11%), or potatoes (-9%).[24]

[22] Marshall Burke, Solomon Hsiang, Edward Miguel, "Climate and Conflict," *Annual Review of the Stanford Economic Review*, 2015, 577.
[23] National Geographic, "How to Live With It: Crop Changes," *National Geographic Online*, 2022, https://www.nationalgeographic.com/climate-change/how-to-live-with-it/crops.html#:~:text=Climate%20change%20may%20actually%20benefit,flooding%2C%20will%20be%20less%20benign.
[24] National Geographic, "How to Live with It: Crop Changes."

Climate change is additionally disrupting the availability, flow, and natural distribution of freshwater sources globally. The extreme weather conditions associated with climate change bring with it longer, more frequent droughts, more irregular and extreme floods, and more wildly unpredictable severe weather. Unbalancing natural water cycles are likely to affect millions—if not billions—over the next several decades (Figure 6).[25] Unfortunately, these effects are likely to impact already-vulnerable populations, particularly the poor, young, and elderly.

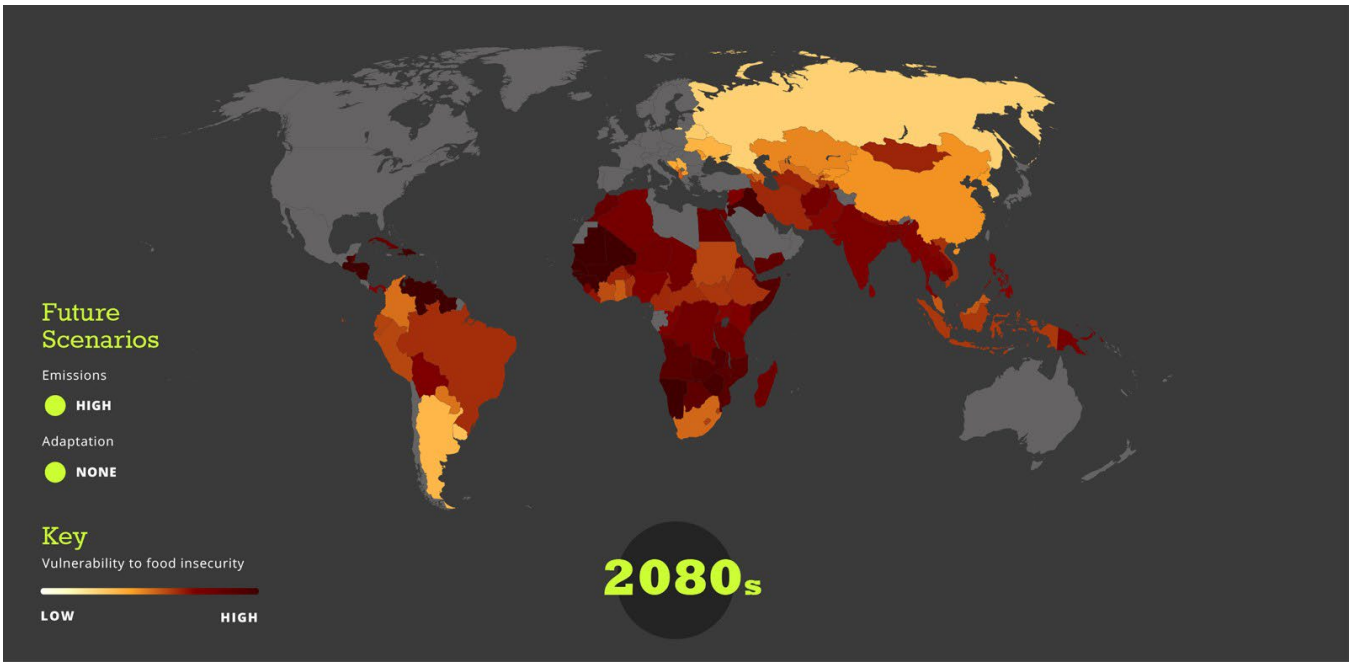

Figure 6 - Models suggest that by 2080, areas of South America, Sub-Saharan Africa, and Southeast Asia, climate change-driven food insecurity will reach "Extreme" levels if current GHG emissions are left unaltered (Source: MetOffice – UK)

Additionally, should greenhouse gas emissions not be addressed, most models predict that wide swaths of the planetary surface, primarily in tropical regions, will become uninhabitable. As such, it will amplify an already-growing group of "climate refugees," vulnerable communities driven from their homes as a result of climate change-induced storms, droughts, floods, heat, or unsustainable crops or water sources.

[25] Met Office and World Food Programme, "Food Insecurity and Climate Change Interactive Simulation," April 2022, https://www.metoffice.gov.uk/food-insecurity-index/.

Just as Burke, et. al., calculated in "Climate and Conflict," each of these effects (and many more) are highly likely to impact global geopolitics and threaten American national security at home and abroad. Should efforts not be made to curb global GHG emissions, climate-driven conflict is more likely to occupy an increasingly larger portion of U.S. resources domestically and abroad.

Installation and Resource Vulnerability to Natural Disasters

In addition to responding worldwide to conventional conflict, climate change will also drain U.S. resources as it responds to a world with larger, deadlier, and more frequent natural disasters. Data analysis of information provided by the International Disaster Database (EM-DAT) and the UK's Centre for Research on the Epidemiology of Disasters (CRED), the frequency of significant severe weather events has increased steadily since 1900, and exponentially since 1960. Additionally, not only have severe weather events been more frequent (Figure 7), but they've also become more costly (Figure 8)—both in terms of money and human lives. In short, more deadly natural disasters are on an upward trend worldwide and pose a threat to the physical and financial infrastructure of America's national security domestically and overseas.

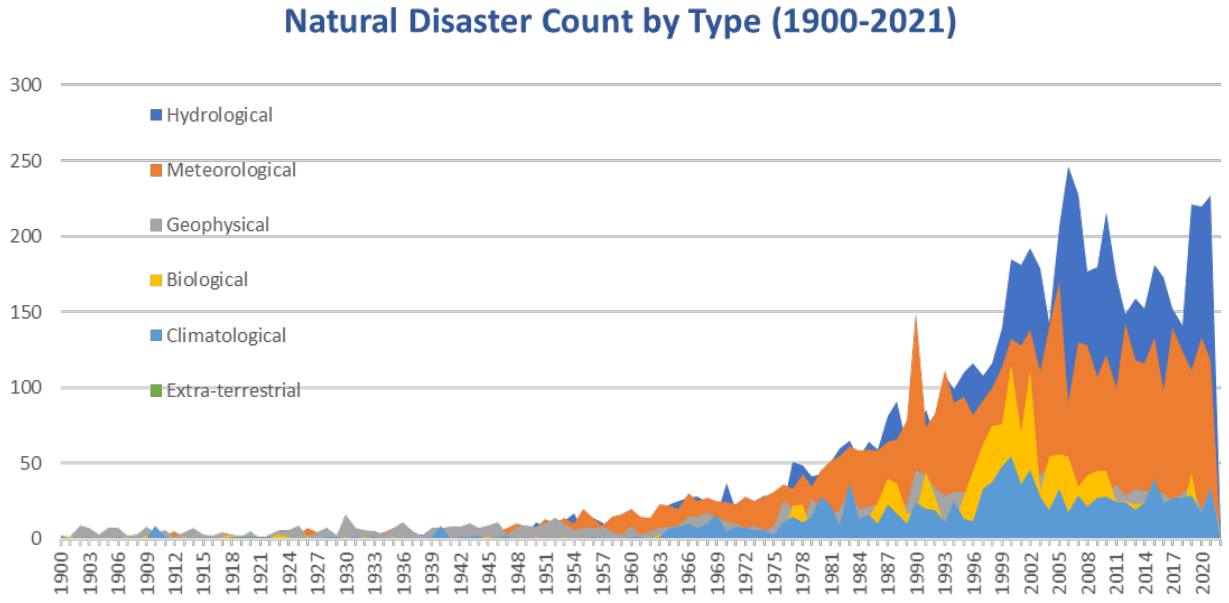

Figure 7 – Indicating the significant increase in quantity of natural disasters in the post-industrial age (Data Source: EM-DAT)

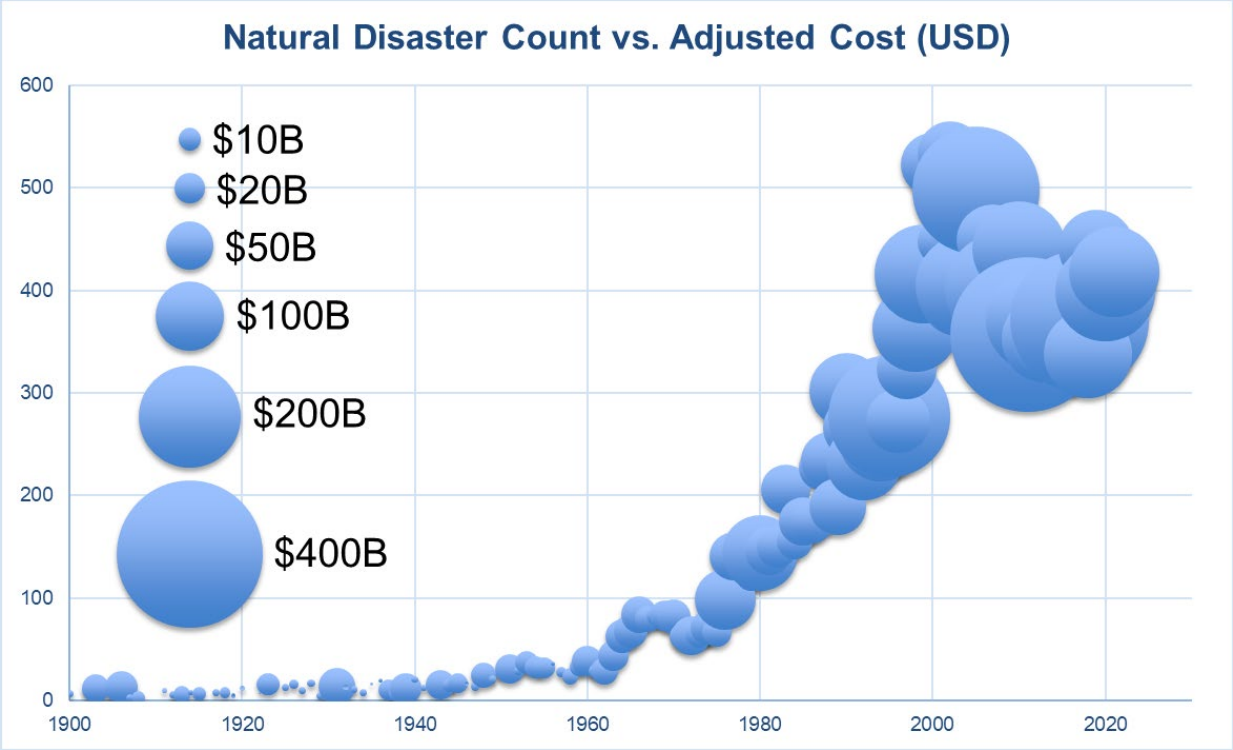

Figure 8 - Natural Disaster Frequency vs. Adjusted Cost in USD, indicative of not only increasing trends of storm frequency, but also of strength as indicated by damage cost (Data Source: Centre for Research on the Epidemiology of Disasters (CRED) and International Disaster Database (EM-DAT))

Even over the last several decades, U.S. installations have felt the immediate and deadly effects of this increase in severe weather. Travis Air Force Base, California, was evacuated several times during the surge of wildfires in the American west in 2020. The island of Guam, a vital strategic asset for U.S. interests in the Pacific, was struck by Category 4 typhoon Pongsona in December 2002, nearly wiping out the island's capabilities while causing an estimated $1.1B USD (2022 adjusted) in damage. Guam remains as the most typhoon (hurricane) vulnerable territory in the United States. In 2018, Category 5 Hurricane Michael all but destroyed Tyndall Air Force Base, home of the 325th Fighter Wing and its fleet of some of America's most advanced—and expensive—fighter aircraft.[26]

[26] Logan Lee, "Military Communities and Natural Hazards in the United States," (Charleston, SC: University of South Carolina Press, 2021), 14.

Increased Demand for Humanitarian Assistance

The cumulative effects of the threats listed above also combine to create a threat now being faced by the international humanitarian community. Increasing incidents of worldwide conflict, instability, natural disasters, and climate migration have driven a large demand on the world's humanitarian resources, and the U.S. military is no exception. According to trend analysis maintained by the U.S. Agency for International Development (USAID), the U.S. has significantly increased its financial and material foreign aid significantly over the last two decades.[27] Analysis of compiled data from USAID and the U.S. State Department indicate a dramatic increase in the frequency of calls for U.S. military assistance over the last 30 years (Figure 9). Should climate change continue unabated, the demand for U.S. humanitarian assistance is highly likely to continue rising and will continue to divert scarce finances, resources, and efforts away from other U.S. foreign interest activities.

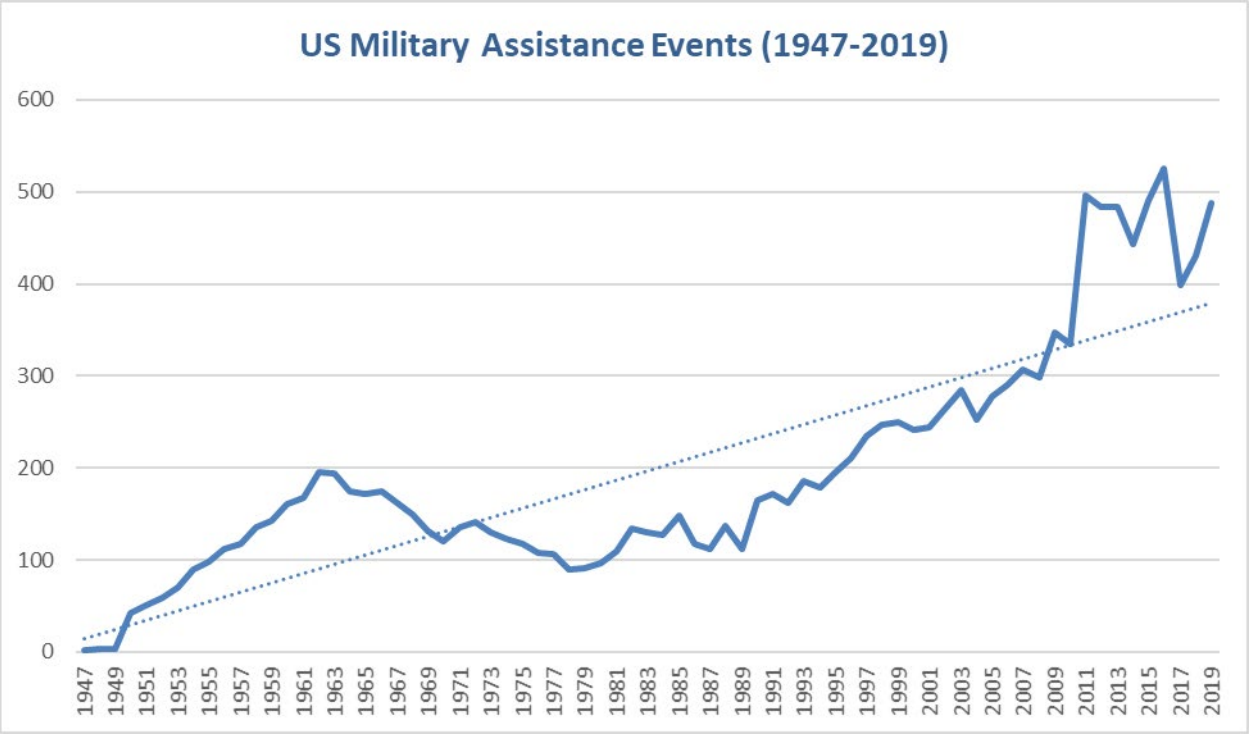

Figure 9 - Visual depiction of U.S. Military Assistance Events, 1947-2019 (Data Source: USAID)

[27] USAID, "Foreign Assistance Aid Trends – Online Interactive Data," April 2022, https://foreignassistance.gov/aid-trends.

Chapter III

Air Force Contributions to Global CO_2 Emissions, 2000-2020

Over the last two decades, the DoD, and specifically the U.S. Air Force, have been extraordinary contributors of global CO_2 emissions globally. If the U.S. military were a sovereign nation, it would rank approximately 56th in the largest consumers of energy in 2019. Dr. Neta Crawford, co-Director of Brown University's *Costs of War Project*, and author of a 2019 report, "Pentagon Fuel Use, Climate Change, and the Costs of War," noted, "the U.S. Department of Defense is the single largest institutional emitter of greenhouse gasses (GHGs) in the world."[28] This is evident not only in the DoD's remarkable acquisition and consumption of energy, but in how that energy is used. DoD energy consumption can generally be broken into two categories: Installation (facility) energy and Operations (vehicles, transportation, and operational activity). These two facets of energy consumption, coincidentally, are two of the highest emitters of CO_2 worldwide.

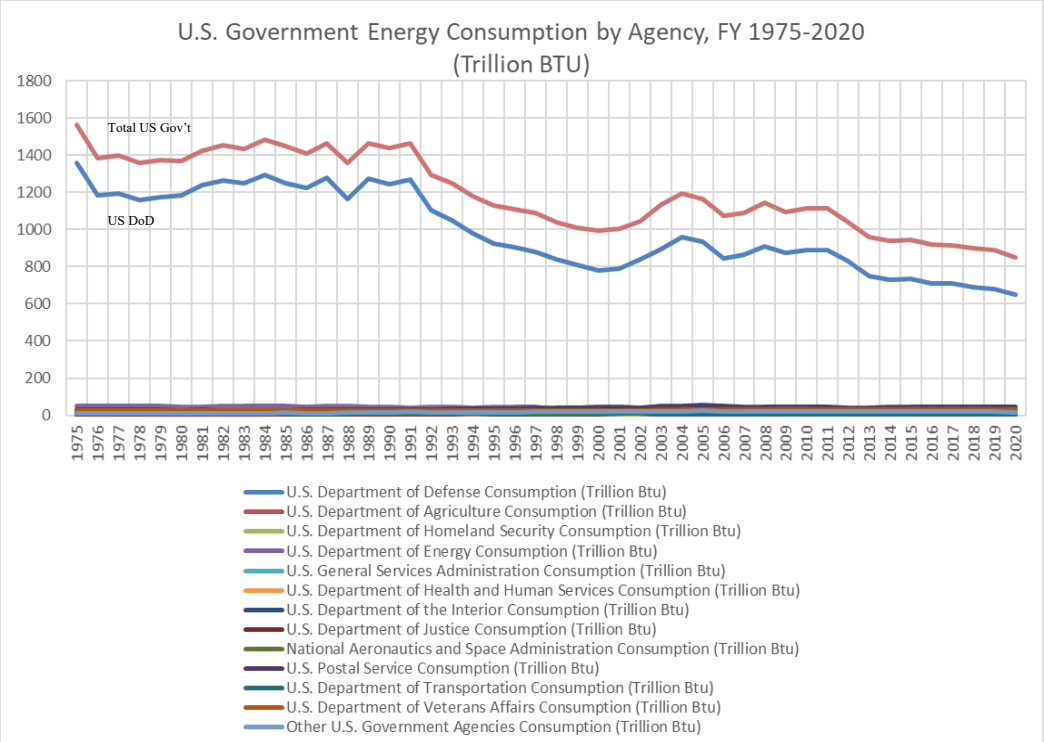

Figure 10 - US Gov't Energy Use, FY1975-2020 (Data Source: USEIA)

[28] Crawford, "Pentagon Fuel Use," 2.

According to the U.S. Department of Energy, vehicles (or, operational energy consumption) accounted for 69% of DoD's Fiscal Year 2020 (FY20) total energy use, and jet fuel consumption accounted for more than half of that DoD total (Figure 11). Facility energy consumption accounted for approximately 31%.[29]

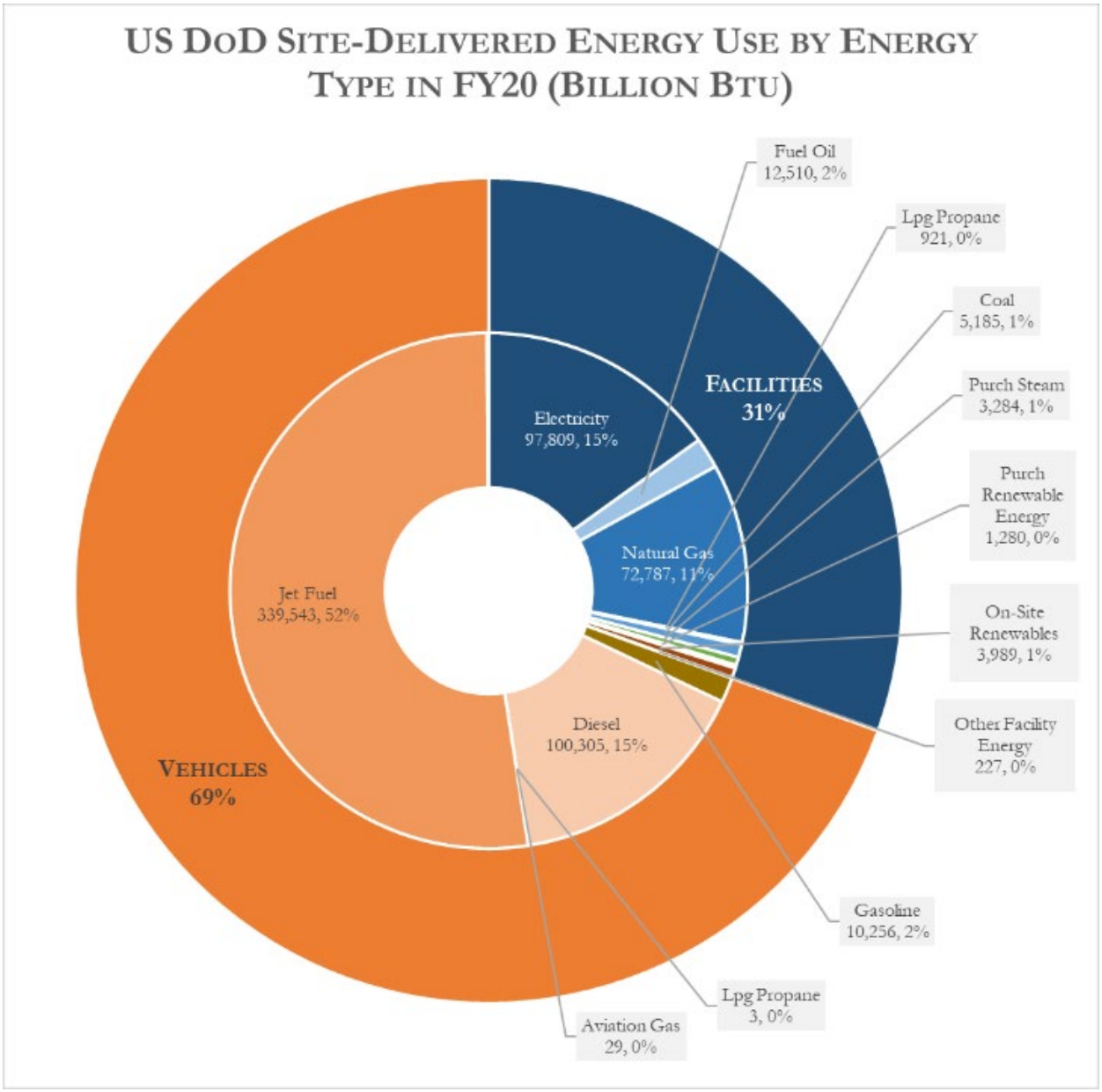

Figure 11 - More than 52% of total US DoD energy use was consumed as jet fuel (Data Source: US DoE)

[29] US Department of Energy, "Comprehensive Annual Energy Data and Sustainability Performance, Online Data," April 2022, https://ctsedwweb.ee.doe.gov/Annual/Report/SiteDeliveredEnergyUseAndCostBySectorAndTypeAndFiscalYear.aspx.

In FY20, DoD consumption was 849 trillion BTUs, compared to total U.S. consumption of 92,954 trillion BTUs, and world consumption of 601,040 trillion BTUs. [30, 31] As such, the DoD is a major contributor to worldwide energy use, and has an obligation to critically examine how that energy is used.

Energy allocations within the Air Force is even more lopsided, with Operational Energy (specifically ground vehicles and aviation operations) accounting for more that 82% of its total energy use (Figure 12). Thus, while operational energy use should be the long-term focus for Air Force energy management, installation energy still accounts for approximately one-sixth of the Air Force's total and should not be neglected.

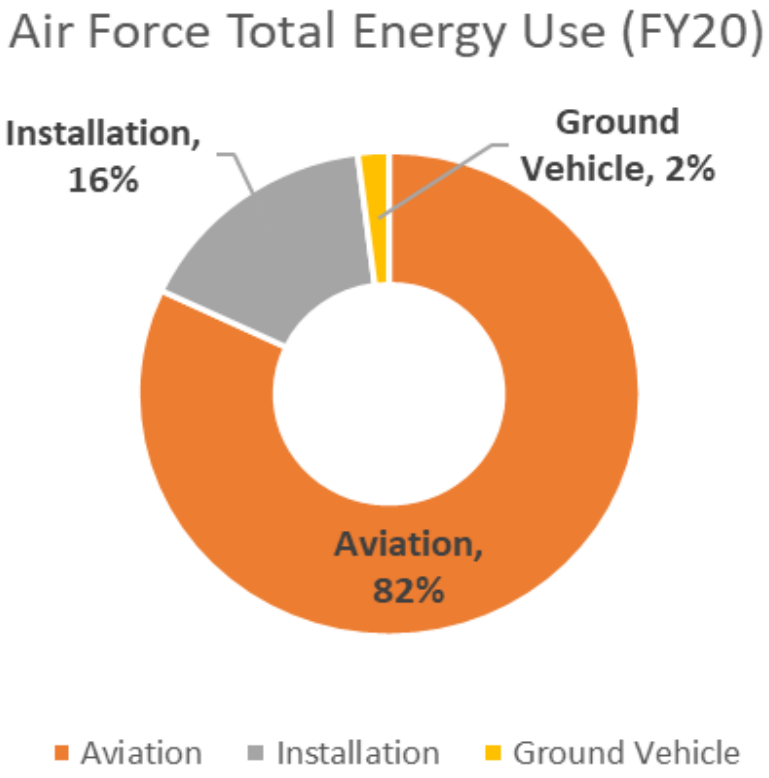

Figure 12 - USAF Total Energy Use, FY20 (Data Source: SAF/IE)

Installation and Infrastructure Energy Requirements

Accounting for 16% of the Air Force's energy use in FY20, installations are a major contributor to total Air Force CO_2 contributions. According to the 2021 Annual Energy Management and Resilience Report (AEMRR), Air Force installations consumed 56 trillion BTUs of energy, largely from fossil fuel sources. This translates as roughly the annual national energy consumption of Uganda and exceeds the

[30] US Energy Information Administration, "Annual Energy Review, Online Data," April 2022, https://www.eia.gov/totalenergy/data/annual/index.php.
[31] US Energy Information Administration, "Total Energy Production, 2020, Online Data," April 2022, https://www.eia.gov/international/rankings/world?pa=12&u=0&f=A&v=none&y=01%2F01%2F2019.

energy consumption rates of 74 other nations.[32] Even using the most conservative estimate (i.e., a majority of energy generated using the cleanest form of fossil fuel, natural gas), this equates to approximately 2.97 metric tons of CO_2 emissions annually.

The recent war between Ukraine and Russia has highlighted concerns about how U.S. military installations are powered, and from which countries the fuel for that energy originates. Research conducted at Brown University's Climate Solutions Lab estimates that as much as 25% of America's European installations are powered using Russian fuel sources. Installations in Germany are particularly vulnerable, as most records show as much as a third of Germany's energy is sourced from Russian oil or coal fields.[33]

Non-Combat Vehicle Fleet Operations

As the smallest of the Air Force's energy requirements, the non-combat vehicle fleet accounts for approximately 2% of its energy consumption. Second only to the U.S. Postal Service, the DoD is the largest maintainer of non-tactical vehicles in the U.S. Government—approximately 170,000 vehicles.[34] While this represents only a fraction of DoD greenhouse gas emissions, this sector of Air Force fuel consumption is likely the easiest to remedy. Indeed, several Air Force installations have begun to replace legacy internal combustion engine (ICE) vehicles with hybrid or electric vehicles. In 2018, Los Angeles Air Force Base became the first installation in the U.S. military with an all-electric vehicle fleet, and the

[32] US Energy Information Administration, "Total Primary Energy Consumption by Country," April 2022, https://www.eia.gov/international/overview/world.
[33] Al Jazeera, "Germany to Halve Imports of Russian Oil by Summer," Al Jazeera Online, 25 March 2022, https://www.aljazeera.com/news/2022/3/25/germany-plans-to-halve-russian-oil-imports-by-summer.
[34] Jon Harper, "US Military Wants Its Vehicles to Go Electric – With Detroit's Help," National Defense Online, 4 February, 2022, https://www.nationaldefensemagazine.org/articles/2022/2/4/military-wants-its--vehicles-to-go-electricwith-detroits-help.

first installation in the world to establish and validate vehicle-to-grid (V2G) technology, which helps sustain local power grids through vehicle charging and battery storage networking.[35]

Aviation and Flight Operations

Aviation and flight operations account for a vast majority of the Air Force's greenhouse gas emissions and total energy use. In 2021, the Air Force is responsible for more than half of all DoD operational energy costs, more than 54% or the equivalent of 41.2 million barrels of oil. Of that portion, mobility aircraft operations (C-17, C-5, C-130, KC-135, KC-10, and KC-46) accounted for more than half of Air Force operational energy use (Figure 13).[36] Aviation operations worldwide account for approximately 3% of total global GHG emissions and is considered to be one of the more CO_2 emitting forms of transportation.

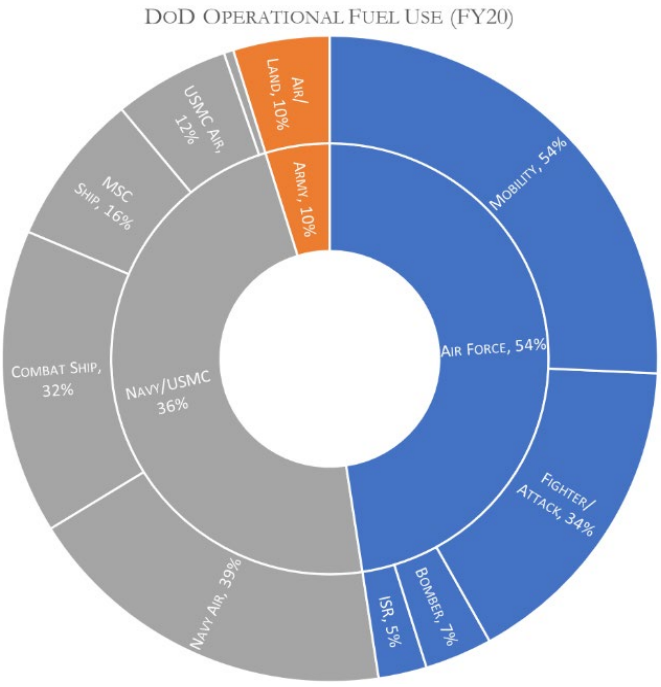

Figure 13 – Nearly 73% DoD's operational fuel was consumed by aviation platforms (Data Source: US DoD)

[35] Douglas Black, et. al., "Los Angeles Air Force Base Vehicle-to-Grid Demonstration," (Los Angeles, CA: California Energy Commission Alternative and Renewable Fuel and Vehicle Technology Program, 2018), 4.
[36] US Department of Defense, "2020 Operational Energy Annual Report," (Washington, DC: DLA Press, 2021), 6.

Chapter IV

Climate Change Threat Adaptation

Promoting Installation Risk Assessments and Disaster Preparedness

The DoD recently launched several initiatives aimed at protecting island and coastal installations and assets. In the 2021 Climate Adaptation Plan, the DoD outlines efforts to "[achieve] resilient built and natural installation infrastructure" through a series of activities, including building installation physical resilience, preserving testing/training space, and protecting ecosystem services.[37] Efforts to address these target areas, while commendable, still lack the granularity needed to be effective. Although the Air Force's Civil Engineer has initiated several efforts to boost installation climate resiliency, only the U.S. Army has released a service-wide comprehensive plan with its 2022 Climate Strategy. In March of 2022, Acting Assistant of the Air Force for Energy, Installations, and the Environment, Mr. Edwin Oshiba, announced the Air Force was on the verge of releasing a new Climate Action Plan, but this plan has not been released to the public at the time of this research publication.[38]

The reach of climate change threats to installations is not limited to shore- or island-based facilities, but also into the Arctic and geographic interior areas. Several Arctic-circle bases were recently highlighted by an April 2022 DOD/IG report as being woefully underprepared for the impacts of climate change on the Arctic. Of the six bases mentioned in the report, four were Air or Space Force assets. Joint Base Elmendorf-Richardson, Clear Space Force Station, Eielson Air Force Base in Alaska, and Thule Air Base in Greenland were all highlighted as "not conducting installation resilience assessments and planning

[37] US Department of Defense, "Climate Adaptation Plan," 12.
[38] Greg Hadley, "Air Force Verges on New Climate Action Plan as European Bases Face Energy Crisis," Air Force Magazine, 16 March 2022, https://www.airforcemag.com/air-force-on-the-cusp-of-releasing-climate-action-plan.

required by DoD directive and public law."[39] Blame for these lapses in planning should not be laid solely at the feet of local installation commanders, however, as the report continues to note that Service Components failed to provide guidance or financial support for such analysis.

Increasing Arctic Presence

The direct effects of climate change are not the only concern for Arctic installations, as they must also face the opening of Arctic sea-lanes and the concerning buildup of strategic military presence by America's near-peer competitors. No doubt in response to the rise in Russian military activity in the Arctic, the Air Force published its first-ever Arctic Strategy Plan in July 2020. This plan spells out the need to, "have a unified, deliberate, and forward-looking approach, ensuring the Air and Space Forces can compete and defend the nation's interests in the Arctic region."[40] While the Arctic Strategy Plan itself is unclassified and available to the public, it is still comprehensive and detailed. It is likely to be helpful in development of classified response plans, and will no doubt be helpful as a guide to further addressing Arctic resiliency issues.

Preventing Conflict and Protecting Resources

The DoD has several initiatives in place, primarily through already-existing conventional mechanisms, to predict future conflict and to protect the resources needed to respond to those conflicts. The advancing effects of climate change are likely to significantly increase the demand for America's resources domestically and internationally, particularly with respect to America's Humanitarian Assistance and Disaster Relief (HA/DR) capability. Four out of the seven geographic areas of

[39] US Department of Defense Office of the Inspector General, "(U) Evaluation of the Department of Defense's Efforts to Address Climate Resilience of US Military Installations in the Arctic and Sub-Arctic," (Washington, DC: DLA Press, 2022), I.
[40] Department of the Air Force, "Department of the Air Force Arctic Strategy," 2.

responsibility surveyed by the 2021 DoD Climate Risk Analysis were designated as areas likely to see a significant increase in demand for HA/DR responses.

Although commissioned by the U.K. Ministry of Defence and focused on British military and foreign aid assets, the 2021 RAND study, "Crisis Response in a Changing Climate," succinctly outlines the need for critical analysis of how climate change-induced effects will affect the U.K.'s ability to with an increasing demand on its HA/DR system. Not only does the report indicate concern that climate change will strain the U.K.'s limited HA/DR capabilities, but the resources and equipment at the tactical level is likely to be at risk. Specifically, "The built environment, including warehouses for critical supplies, energy grids, telecommunications infrastructure and roads, as well as the local population's housing and businesses, may be eroded or destroyed due to climate disasters."[41]

Just as the DoD spends considerable time and resources protecting its combat capability, it is vitally important to also ensure the protection of HA/DR materials, and to prepare for the most efficient employment of those materials. Unlike ever before, however, the resources required to execute the HA/DR mission are themselves vulnerable to the effects of climate change.

Reduced Reliance on Petroleum-Based Capabilities

Recognizing that reliance on fossil fuels is both a logistical vulnerability and a major contributor to global GHG emissions, the Air Force has also dedicated considerable effort to both reducing the number of fuels it consumes, and to finding alternative forms of energy capable of sustaining its warfighting capability. Programs like AFWERX's "JIGSAW" software, which aims to maximize flight planning fuel efficiency and planning, are key to this effort. By expanding JIGSAW-style software and planning across

[41] Lucia Retter, et. al., "Crisis Response in a Changing Climate," (Cambridge, UK: RAND Corporation Press, 2021), p. 46.

all fuel-consuming platforms, the Air Force is likely to significantly reduce its energy footprint while it investigates other forms of clean energy.

Chapter V

Climate Change Threat Mitigation and Reducing GHG Emissions

In addition to multiple climate change adaptation efforts, the DoD maintains several programs aimed at mitigating the effects of climate change rather than simply adapting to it. Specifically, these efforts aim to reduce the Air Force's GHG footprint. Should these programs be successful and should the Air Force reach DoD-stated net-zero carbon emission goals, it is very likely to influence global climate change reversal efforts. To successfully cover the variety of Air Force emissions sources, their approach must be multi-layered and nuanced, involving installation, operational, and defense industry-partner sectors.

Installation Clean Energy Programs

Since the turn of the 21st Century, the Air Force has supported and funded multiple efforts to reduce fuel consumption and reduce GHG emissions, with particular emphasis on its domestic installations. The Air Force Civil Engineer Center (AFCEC) leads many of these efforts, aiming to evaluate and adopt—if feasible—energy efficiency and renewable energy (RE) projects Air Force-wide. Both efforts have been moderately successful. According to its own research, Air Force installations have reduced their energy consumption by 30% since FY94, and maintains more than 30 sustainable energy programs around the Continental United States (CONUS).[42] By incorporating landfill gas, wind, solar/photovoltaic, and geothermal energy sources—generating anywhere from 1 to 56 megawatts of energy, the Air Force has created low-emission options that simultaneously boost the resiliency and energy security of these installations (Figure 18, Annex B).

[42] US Air Force Civil Engineer Center, "Renewable Energy Projects," 2022, https://www.afcec.af.mil/Home/Energy/Renewable-Energy/#:~:text=The%20Air%20Force%20is%20taking,in%20operation%20or%20under%20construction..

AFCEC and Air Force Energy teams have also begun fielding microgrids, adding to the efficiency and resilience of on-base energy systems. A microgrid links several buildings and control stations in a network with the conventional electrical grid, providing a series of backups and controls that, when linked to solar, wind, or other renewable energy sources, could provide nearly unlimited and uninterrupted power sources. Originating as a pilot project at Kirtland Air Force Base in 2019, the Air Force now has several microgrids in place or in development around the world.[43]

Perhaps one of the more interesting advances into renewable and secure installation energy is the Air Force's microreactor pilot program. Using small amounts of low-yield nuclear material, the microreactors are a safe, transportable, highly capable source of renewable and carbon-free energy capable of powering most military installations. Some new microreactors, like that being developed by the company Oklo, can even be fueled by the spent rods of larger, commercial grade conventional nuclear reactors.[44] Capable of providing up to 5-Megawatt Equivalent (MWe) of power, microreactors have the ability to power entire installations with negligible carbon emissions. The Air Force's microreactor pilot program is set to begin in 2027 at Eielson Air Force Base, which currently powers itself using 500-800 tons of coal each day at its independent coal-fired powerplant.[45]

Low- or Zero-Emission Aviation Operations

As the far-and-away largest emitter of GHGs in the DoD's energy mix, the Air Force's aviation operations have a long way to go to achieve net-zero emissions. Several initiatives are ongoing within the

[43] Austin Prisbrey, "Advanced Renewable Energy Microgrid Project Hosted at Kirtland," Air Force Undersecretary for Energy Installations, and Environment, 11 September 2019, https://www.safie.hq.af.mil/News/Article-Display/Article/1990422/advanced-renewable-energy-microgrid-project-hosted-at-kirtland/.
[44] Catherine Clifford, "Oklo has a plan to make tiny nuclear reactors that run off nuclear waste," CNBC Online, 28 June 2021, https://www.cnbc.com/2021/06/28/oklo-planning-nuclear-micro-reactors-that-run-off-nuclear-waste.html.
[45] James Conca, "US Air Force Base to be First to Deploy New Nuclear 'Microreactor'-Soon Every Town Could Have One," *Forbes Magazine*, 1 November 2021, https://www.forbes.com/sites/jamesconca/2021/11/01/us-picks-eielson-air-force-base-for-the-air-forces-first-nuclear-microreactor/?sh=3be30a4e3983.

Air Force Operational Energy Office aimed at reducing energy needs while simultaneously investigating new technologies to boost resilience while reducing the Air Force's GHG footprint.

Like AFWERX's "JIGSAW" program, the Air Force Operational Energy Office pursued and acquired a new mission planning tool, "Puckboard," to maximize fuel planning and operational efficiency. Additional, small-scale efforts like addition of efficiency-producing micro-vanes or finlets on Air Mobility Command's largest carbon emitting aircraft—the C-17A Globemaster III, KC-135 Stratotanker, and C-130 Hercules—have led to incremental (up to 5-10% in some cases) reduction in fuel requirements.

Even as it implements these rapid-execution efforts to reduce fuel use on its existing fleet, the Operational Energy Office is simultaneously finding alternative sources of fuel. In 2008, the Air Force tested—and subsequently certified for use—sustainable aviation fuels (SAFs) on several of its mobility and combat aircraft. Although the program proved technologically successful, it was not cost-comparative to traditional fossil fuels. As 10 USC 2922H prohibits the government from purchasing fuel sources that are not cost-comparative, the program was eventually scrapped as infeasible.[46]

Although the future of SAFs is bright—and in fact several major airlines are now investigating purchasing synthetic aviation fuels as they become more cost-competitive—the Air Force is also making promising new inroads on developing technology that could create fuels "out of thin air." The process of capturing and converting existing atmospheric CO_2, known as Carbon Capture and Transformation (CCT), has improved significantly over the last decade, and in 2021 the Air Force partnered with a promising new

[46] James Decker, "US Air Force Tests Synthetic Fuel in CFM56," Flight Global Online, 23 January 2008, https://www.flightglobal.com/us-air-force-tests-synthetic-fuel-in-cfm56/78406.article#:~:text=The%20US%20Air%20Force%20has,in%20military%20and%20civil%20aviation.

company Twelve to investigate the feasibility of employing drop-in ready CCT-created sustainable fuels.[47]

The employment of SAFs, however, would only be a bridge to achieving fully carbon-free or carbon-neutral operations. To achieve this goal, the Air Force has begun several efforts to beta-test purely electric aircraft. Using its recently created Agility Prime program, the Air Force partnered with several commercial aviation designers to develop an electric vertical takeoff and landing (eVTOL) aircraft. Through Agility Prime's accelerated development program, AFWERX recently completed test flights with Beta Technologies *Alia* and Kittyhawk Technologies *Heavyside* electric aircraft.[48] Should these technologies continue to develop, they are likely to revolutionize both the military and commercial aviation markets. Indicative of the commercial possibilities of EV aircraft, several U.S. airlines have expressed interest in developing and marketing carbon-free flights. Cape Air, a small commuter airline based in New England, recently announced their plan to purchase 75 electric *Alice* aircraft built by the EV pioneering aircraft company, eViation.[49] Should the military continue its interest in EV aircraft, it is likely to drive down production costs and make widespread development and use of EV aircraft more available to the commercial aviation industry.

DoD Influence Over Industry

Reducing or eliminating the Air Force's carbon footprint isn't the only advantage to developing and nurturing alternative energy sources. With the deepest pockets of any U.S. government agency, the

[47] Corrie Poland, "The Air Force Partners with Twelve, Prove It's Possible to Make Jet Fuel out of Thin Air," Air Force Undersecretary for Energy, Installations, and Environment, 22 October 2021, https://www.safie.hq.af.mil/News/Article-Display/Article/2819677/the-air-force-partners-with-twelve-prove-its-possible-to-make-jet-fuel-out-of-t/.
[48] Katie Milligan, "AFWERX Agility Prime Completes First USAF-piloted flight of an eVTOL Vehicle with Partner Kitty Hawk," AFWERX Public Affairs, 21 January 2022, https://www.af.mil/News/Article-Display/Article/2906946/afwerx-agility-prime-completes-first-usaf-piloted-flight-of-an-evtol-vehicle-wi/.
[49] Associated Press, "Commuter Airline to Buy 75 Washington-Built Electric Planes," AP News, 20 April 2022, https://www.bostonglobe.com/2022/04/20/business/cape-air-buys-75-electric-planes/.

DoD has enormous influence over commercial industry, particularly with those linked to defense production. By indicating interest in renewable technologies, the DoD is likely to prompt additional development in carbon-free technology, fostering scalability and making them more accessible to the non-defense world. Thus, the DoD, uniquely positioned as a non-profit-driven entity, can affect reduction of GHGs globally.

American history is filled with examples of defense research (or defense spending) creating revolutionary technologies that end up changing the world. Radar, microwaves, the internet, satellite communications, and of course nuclear power all derived from military research and development. With additional DoD emphasis on promoting sustainable technology, it is highly likely to catalyze further development around the world.

Air Force Future System Programs of Note

Several Air Force-sponsored emerging technologies are particularly promising to meaningfully contribute to carbon-free or carbon-neutral development and deserve consideration and further support. These technologies—poised to turn energy security and climate security on their heads—are likely to be major players in future renewable energy and carbon-free defense operations.

SSPIDR Program (Northrop Grumman/AFRL)

A joint effort between Northrop Grumman and the Air Force Research Lab (AFRL), the Space Solar Power Incremental Demonstrations and Research (SSPIDR) Project aims to collect solar power via satellite based orbital photovoltaic arrays, convert that energy into HF beams, and transmit it to the Earth's surface where it can be distributed as electricity. This technology would require the deployment of mobile "receiver" arrays—now in development—for ground forces to convert and distribute the energy. This process, however, would ensure unlimited, reliable, uninterruptible, and immediate energy to ground

forces and could dramatically increase the feasibility of electrification of military and commercial vehicles.[50]

eJet CCT Synthetic Fuels (Twelve/AF Operational Energy Office)

One of the Air Force's first scalable efforts to propagate synthetic aviation fuels via carbon capture and transformation was the Operational Energy Office's 2020 endorsement of Twelve, a growing team of electrochemists and material researchers based out of the Berkeley National Labs in California.

Twelve's technology uses a CCT energy-efficient electrolysis process to convert captured environmental carbon into aircraft-ready drop-in synthetic fuels. The "highly deployable and scalable" system is unprecedented in its speed, efficiency, and low cost. While it's unlikely to meet the requirements of being "cost comparative" to traditional fossil fuels—particularly if fossil fuels continue to receive extraordinary government subsidies to reduce consumer costs—it's the first step to making CCT-created SAFs scalable and cost effective.[51]

[50] Nathan Strout, "Air Force Research Laboratory Is One Step Closer to Beaming Solar Energy from Space to Earth," C4ISRNet News, 22 December 2021, https://www.c4isrnet.com/battlefield-tech/space/2021/12/22/air-force-research-laboratory-is-one-step-closer-to-beaming-solar-energy-from-space-to-earth/.
[51] Poland, "The Air Force Partners with Twelve."

Chapter VI

Recommendations and Conclusions

Recommendation 1: Zero Emission Installation Pledge

Institute requirements for all Air Force installations to employ net-zero facility energy use by 2050. This can be achieved by amplifying current efforts to pursue solar, wind, geothermal, and micro-reactor nuclear energy sources. Current Air Force programs are a good start, but currently lack a stated objective. Headquarters Air Force should adopt targets like those of the Army Climate Strategy, and pledge to reduce installation-created GHGs 50% by 2035 and GHG-free by 2050.[52] Achieving these audacious goals will require an all-of-service effort and is likely to involve a variety of sustainable energy sources.

Recommendation 2.1 (Short Term): Proliferate Drop-in Synthetic Jet Fuels

Most processes which produce Synthetic Aviation Fuels (SAFs) are shown to reduce overall carbon emissions by 85%.[53] While SAFs have been "drop-in capable" for nearly 40 years, and the commercial airline industry is growing increasingly interested in their employment. In fact, the DoD—and U.S. Air Force specifically—has already developed, tested, and field-proved the capabilities of SAFs as a drop-in alternative to petroleum-based fuels in programs dating as far back as 2008.[54] However, even though SAFs have been certified for use in several U.S. fighter, bomber, and airlift major weapons systems, the program was eventually halted, as the higher costs of SAF prohibited the DoD from making bulk purchases as a result of provisions in 10 USC 2992H.

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[52] Joseph Lacdan, "Army Introduces Strategy to Combat Climate Change Threats," Army News Service, 10 February 2022, https://www.army.mil/article/253863/army_introduces_strategy_to_combat_climate_change_threats#:~:text=The%20Army's%20innovation%20plans%20also,from%20Army%20installations%20by%202050.

[53] Terry Slavin, "Airlines Seek Clearance for Liftoff on Sustainable Aviation Fuels," Reuters News Online, 18 April 2022, https://www.reuters.com/business/sustainable-business/airlines-seek-clearance-liftoff-sustainable-aviation-fuels-2022-04-18/.

[54] Breanne Wagner, "Market for Synthetic Aviation Fuels Off to a Shaky Start," National Defense Magazine, 1 May 2008, https://www.nationaldefensemagazine.org/articles/2008/5/1/2008may-market-for-synthetic-aviation-fuels-off-to-a-shaky-start.

Recommendation 2.2 (Short Term): Pursue DoD waiver to 10 USC 2922H

10 USC 2922H requires that DoD large-scale fuel purchases be "cost-comparative," which limits the immediate purchase of SAFs, even if SAF costs are only marginally higher than that of its fossil fuel equivalent. A waiver to 10 USC 2992H specifically permitting the purchasing of non-fossil fuel-based alternatives would not only reduce the DoD's overall carbon footprint but would become an industry signal supporting the future of SAF development. Economic consensus agrees that such a waiver would boost overall SAF production and drive down prices. Such a waiver would cement SAF as a future alternative in the commercial market and drive scalability of future SAF technology.

Recommendation 2.3 (Short Term): Rewrite the National Security exception to EO 14507

In December of 2021, President Joe Biden signed Executive Order #14507, directing all federal agencies to—among other carbon-reducing goals—source 100% of their energy from annual net carbon-free sources, achieve net-zero emissions building portfolios by 2045, ensure all new vehicle acquisitions are zero emission vehicles by 2035. While these goals are commendable, aggressive, and very likely to reduce the GHG footprint of nearly all government agencies, there is one notable caveat.

Section 602(a) "Exemption Authority," states, "The head of an agency may exempt particular agency activities and related personnel, resources, and facilities from the provisions of this order when it is in the interest of national security," and section (b) extends the head of agency exemption authority to also include, "any vehicle, vessel, aircraft, or non-road equipment that is used in combat support, combat service support, military tactical or relief operations, or training for such operations or spaceflight vehicles, including associated ground-support equipment."[55] While the current Secretary of Defense has

[55] Office of the President of the United States, "Executive Order on Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability."

indicated an interest in aggressively addressing the DoD's carbon footprint, this exemption authority, as written, provides inordinate authority to exempt nearly all operations within the DoD. As the agency responsible for more than 76% of U.S. Government energy consumption and carbon emissions (Figure 17, Annex B), the DoD has the lion's share of responsibility in cutting government induced GHG emissions. Even if the EO is followed and all stated goals met, the overall reduction in GHGs would be miniscule without full DoD compliance.

While the considerations of national security interests in the exception is commendable, it provides far too much latitude for non-compliance. The EO should be rewritten to ensure compliance of the U.S. government's largest GHG-emitter while still considering national security concerns. In short, GHG reduction programs and ensuring national security interests are not mutually exclusive, and often, in fact, support one another.

Recommendation 2.4 (Mid Term): Further Fund Carbon Transformation Jet Fuel Technology

The Air Force's early investments in Carbon Capture and Transformation technology—namely with Twelve Technology's *eJet* CCT synthetic fuel—are an excellent start. However, to maximize scalability and minimize cost, the Air Force should further fund CCT research and invest heavily in miniaturization, transportability, and development of future CCT systems. As previously noted, SAF blends have already been certified for drop-in use in several DoD aircraft. Thus, CCT-created SAFs would act as a perfect transition from the Air Force's legacy fossil fuel-powered fleet to its next sustainably fueled fleet.

Recommendation 2.5 (Long Term): Invest in Zero-Emission Aircraft

Air Force research and development teams, specifically AFWERX and the Air Force Research Labs, have made significant strides towards advancing and developing zero-emission aircraft. However, while their focus has primarily been on single-occupant eVTOL aircraft and solar-powered remotely piloted or autonomous aircraft, they are quickly being outpaced by commercial development. Aircraft manufacturers like eViation, Airbus, Boeing, and Lockheed are all rapidly developing the future of electrified and zero-emission aircraft. The Air Force would benefit from additional funding of research and test flight of both organically developed and off-the-shelf technologies for military use.

Recommendation 3: *Manhattan Project* for Climate Security

Finally, the Air Force's biggest impact globally will not be its own GHG-curbing policies, but the secondary and tertiary effects of those activities. The DoD has wide reach, and is uniquely postured as an extremely well-funded, non-profit based, highly technological institution. The U.S. currently lacks a centralized set of climate goals, nor does it authorize a single entity to lead the technological research, policy development, and program execution.

The U.S. once faced a similar global life-threatening event, wherein a whole-of-government approach was needed to save American lives. Officially formed in August 1942, the *Manhattan Project* was born out of a need to develop technology that could halt the deadly advance of World War II. The *Project* brought together America's top scientists and academics with the might, authority, and funding of the U.S. DoD, then operating as the War Department. Their efforts, a delicate balance of military and civilian authority, brought forth the nuclear age.

As the effects of global climate change once again place the future of American national security—and indeed global security—at stake, the U.S. has an opportunity to once again lead. Establishing a

Manhattan Project for Climate Security, again bringing together our nation's best researchers and its national security enterprise, could once again usher the world into a new age of peace and security.

Chapter VII

Conclusion

Military planners have too-long operated under the assumption that global climate change is something over the horizon and unworthy of consideration for short- or mid-term planning. Unfortunately, the effects of climate change are here today, and will continue to adversely affect every facet of America's national security interests domestically and abroad.

Climate change is the thread that runs through every single military operation, whether it be via how the Air Force powers its installations, how our bases and equipment deal with the rising tide of natural disasters and severe weather, or the destabilization of an already-fragile balance of powers around the world.

The ideal time for action has already passed, and the window to make up for lost time is rapidly diminishing. The Air Force and the DoD must amplify its efforts to adapt and mitigate its operations to the effects of climate change. Understanding the threats, developing responses to countering those threats, and eliminating or changing operations that actively amplify these threats, are key to countering the serious challenges posed by climate change.

The DoD exerts tremendous influence over America's—and the world's—commercial, industrial, and socio-economic *status quo*, and as the world's largest institutional emitter of greenhouse gasses, it has a moral responsibility to act. The DoD can—and should—lead the world's effort to combat climate change. Just as it has so many times before, America is poised to lead the world through catastrophe. What the world needs now is a single, consolidated, focused effort to combat a global threat unlike any other witnessed in world history, and the U.S. DoD is one of the only institutions on the planet capable of leading it.

APPENDIX A – Historical Trends in U.S. Foreign Aid

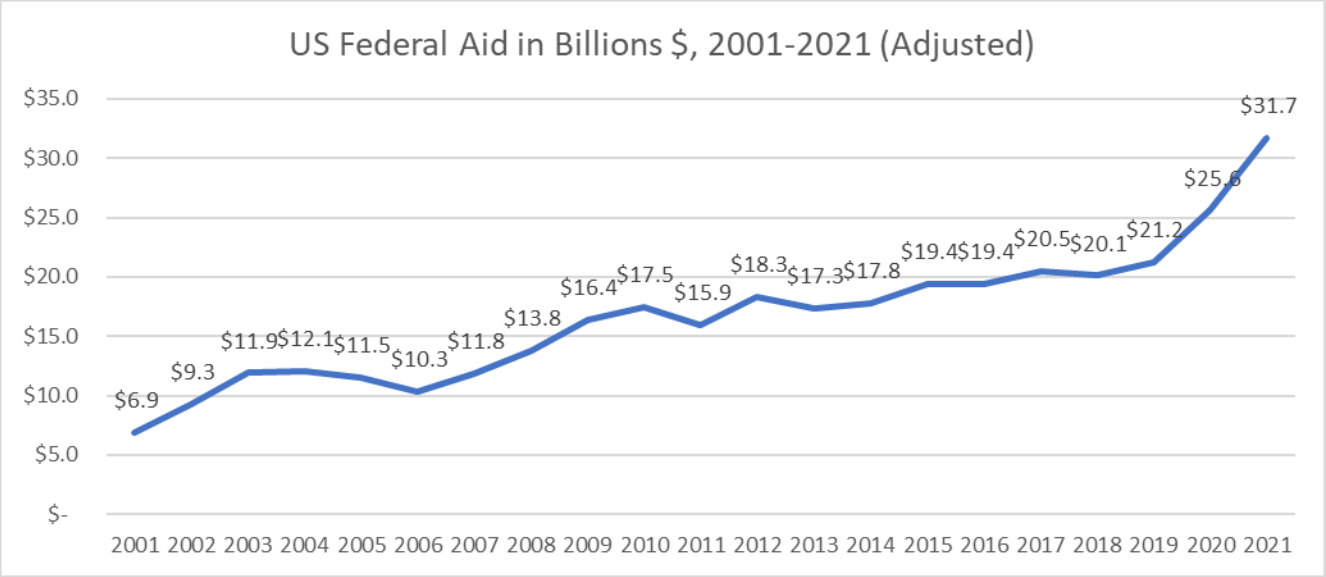

Figure 14 - US Foreign Aid in billions of US Dollars, 2001-2021 (Adjusted) (Data Source, USAID)

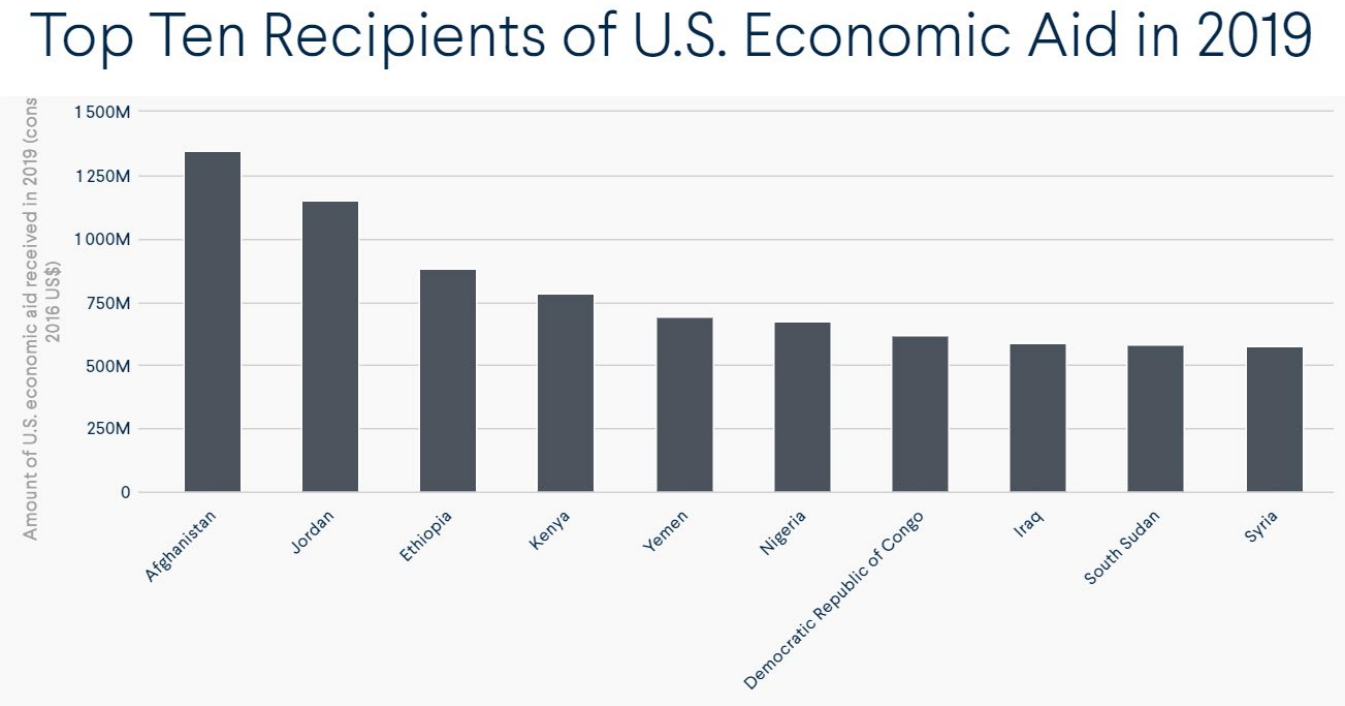

Figure 15 - USAID Depiction of Top 10 Recipients of US Economic Aid in 2019 (Source: USAID)

APPENDIX B – U.S. Government Energy Use

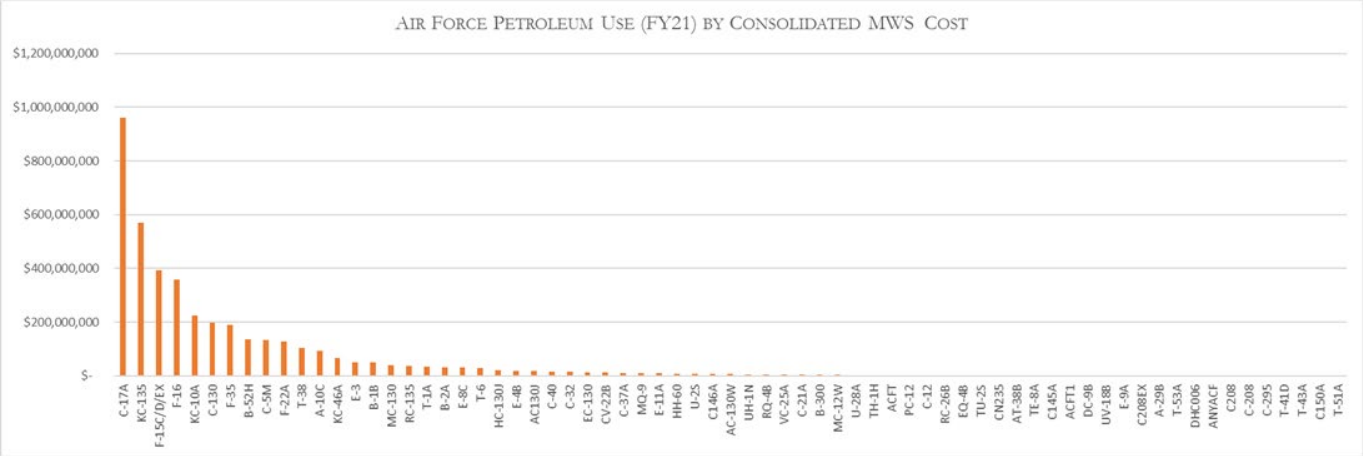

Figure 16 - Breakdown of USAF Operational Fue Costs by MWS, FY21 (Data Source, SAF/IE)

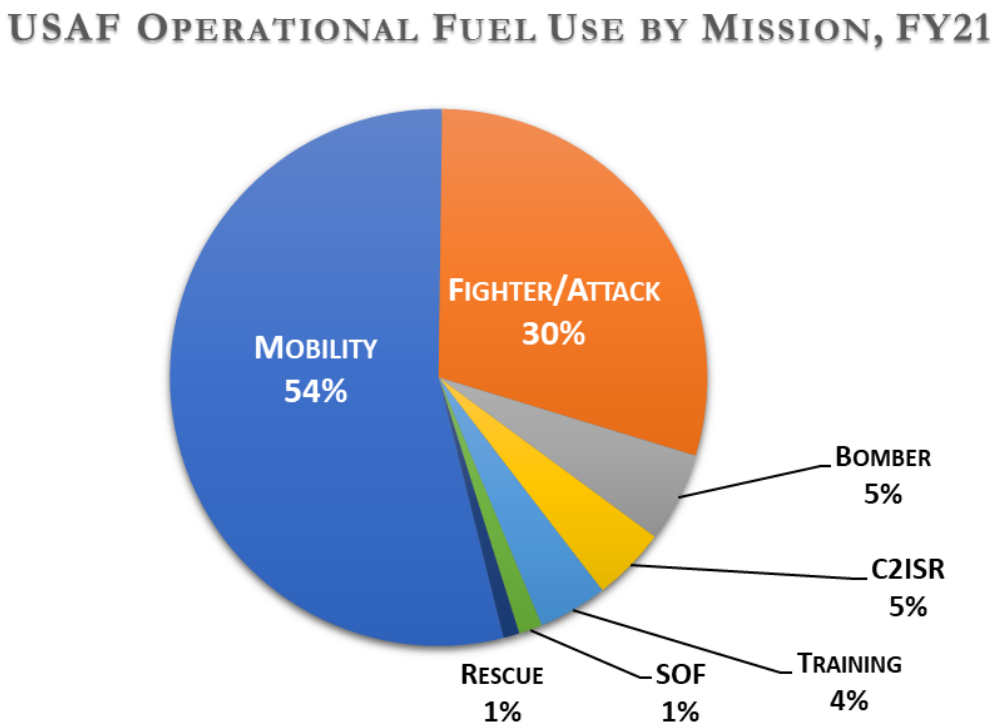

Figure 17 - Breakdown of USAF Operational Fuel Use by Aircraft Mission, FY21 (Data Source, SAF/IE)

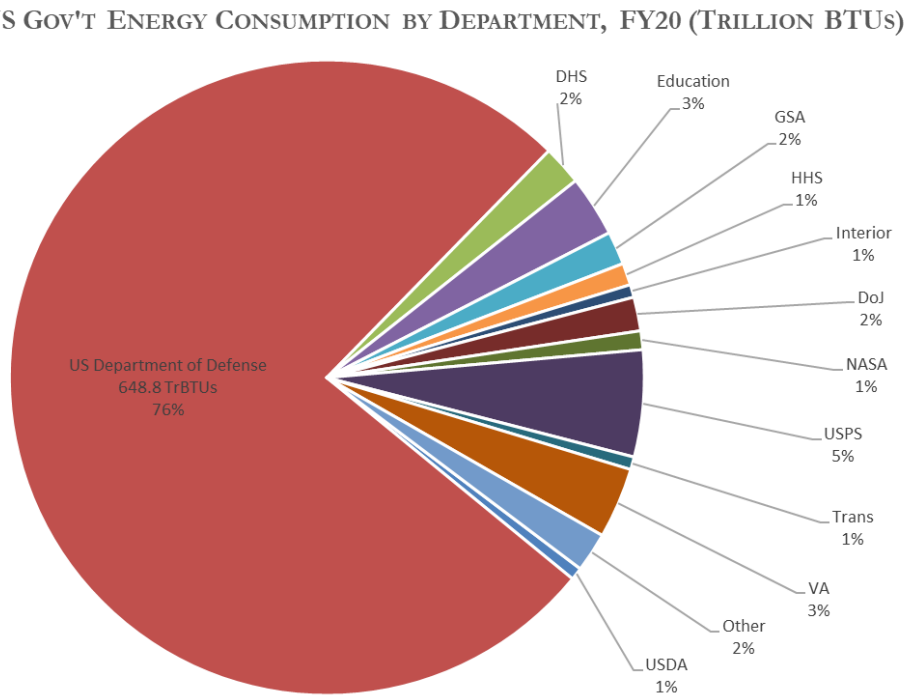

Figure 18 - Breakdown of energy consumption by department/agency, FY20 (Data Source: US EIA)

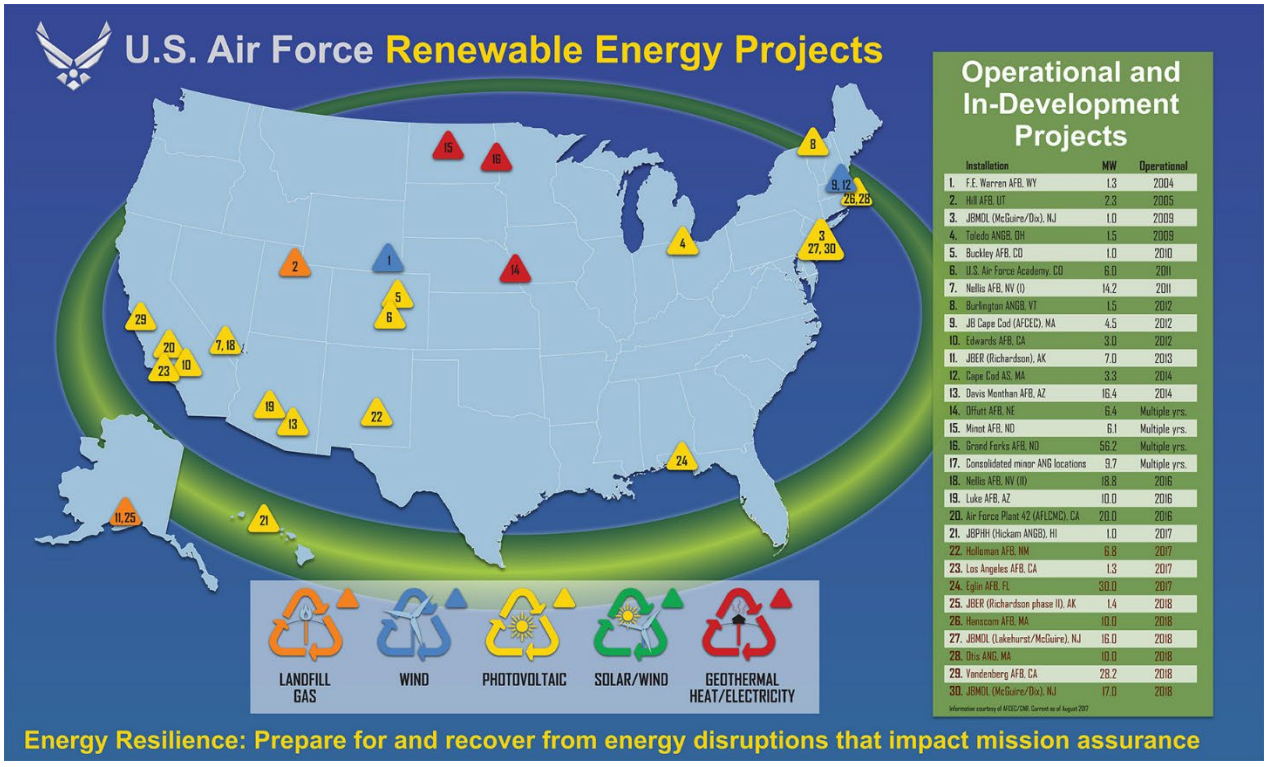

Figure 19 - AFCEC-Led CONUS Installation Sustainable Energy Projects (Source: AFCEC)

GLOSSARY

AEMRR	Annual Energy Management and Resilience Report
AETC	Air Education and Training Command
AFCEC	Air Force Civil Engineer Center
AFRL	Air Force Research Laboratory
CCT	Carbon Capture and Transformation
CCS	Carbon Capture and Sequestration
CRED	Centre for Research on the Epidemiology of Disasters
DoD	Department of Defense
DoE	Department of Energy
EO	Executive Order
EIA	Energy Information Administration
GCC	Global Combatant Command
HA/DR	Humanitarian Assistance/Disaster Response
ICE	Internal Combustion Engine
NOAA	National Oceanic and Atmospheric Administration
NSS	National Security Strategy
SAF	Synthetic Aviation Fuel
SAF/IE	Assistant Secretary of the Air Force for Energy, Installations & Environment
SSPIDR	Space Solar Power Incremental Demonstrations & Research
USAID	U.S. Agency for International Development
V2G	Vehicle-to-Grid

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