SCUSA 72 Table Paper: Climate Change

Major James "Jim" R. Hughes

In the past, the US has failed to unite behind international efforts to combat climate change by implementing emissions reductions. Past attempts to slow climate change, including the Kyoto Protocol (which the US Senate refused to ratify), foundered on domestic political disputes over the value and need for such agreements. Most recently, U.S. Administrations have entered, rejected, and now re-entered the Paris Climate Accords. Despite, or because of, these halting efforts, the impact of climate change continues unabated, negatively affecting increasing parts of the global population, through devasting storms, desertification, and rising sea levels. How can the United States adapt new, disruptive technologies to meet this challenge? And how might the negative effects of policy responses to climate change, including losses in industries based on fossil fuels, be tempered? How is climate change, and responses to climate change, affecting the balance of power across the world and reshaping international relations? How might climate change impact U.S. economic and military dominance? To what extent can new technologies reduce global warming and slow, halt, or reverse the environmental damage?

Introduction

Climate change is pervasive in modern discourse, affecting scientific research, public policy, business strategies, international relations, and many other areas. Often climate change is discussed in a political context. Is climate change fundamentally a scientific issue or a political issue or is this a false dichotomy? Arguably, the reason that climate change dominates modern discourse is because it is fundamentally a political issue. Although understanding and describing the physical processes of climate change is a scientific topic (which continues to develop), the most critical aspect of climate change is the policy and actions that we take based on this scientific evidence. This paper focuses on U.S. policy regarding the global issue of climate change.

Climate change is increasingly accepted as fact by the U.S. population, as noted by a Morning Consult poll, with 50% of voters considering climate change as a "critical threat", a 10% increase from June 2017.[1] This is not to say that all the implications of climate change are well established, but arguably there is sufficient evidence to convincingly move forward to adapt to and mitigate climate change. Technology continues to play a critical role in adapting to and mitigating climate change. To provide context, this paper first summarizes the significant focus on climate change in the latest U.S. national security strategic guidance. Then the paper presents a foundation of the scientific evidence for climate change, expected impacts of climate change, and the role of technology in addressing climate change.

Climate Change and National Security Policy

President Joseph Biden issued Interim National Security Strategic Guidance in March 2021, in which climate change plays a prominent role.[2] The term "climate" is referenced 27 times, "climate change" 14 times, and "climate crisis" five times. President Donald J. Trump's National

Security Strategy (NSS) from 2017 does not include the phrase "climate change" and "climate" only makes four appearances (with three of the instances referring to business or investor/friendly climate).[3] From this you might assume that these policies are completely divergent, but President Trump's NSS does emphasize the role of reducing greenhouse gases as well as the role of technology:

> The United States will remain a global leader in reducing traditional pollution, as well as greenhouse gases, while expanding our economy. This achievement, which can serve as a model to other countries, flows from innovation, technology breakthroughs, and energy efficiency gains, not from onerous regulation.[4]

President Biden places greater emphasis on climate change within the national security policy. This difference highlights the political (or policy) nature of dealing with a changing climate. Even President Trump implied a need to address climate change by referring to a reduction in greenhouse gases.[5] President Biden's strategy gives a good introduction of how climate change fits into U.S. national security, while also indicating the role of technology.

President Biden addresses "a revolution in technology that poses both peril and promise", highlighting the potential for clean energy to slow climate change.[6] In this case technology is a positive aspect to be embraced. He goes on to highlight the need for collective action and the co-benefits of addressing climate change, which include economic considerations.

> We have already re-entered the Paris Climate Accord and appointed a Presidential Special Envoy for climate, the first steps toward restoring our leadership and working alongside others to combat the acute danger posed by rapidly rising temperatures…if we fail to act now, we will miss our last opportunity to avert the most dire consequences of climate change for the health of our people, our economy, our security, and our planet. That is why we will make the clean energy transformation a central pillar of our economic recovery efforts at home, generating both domestic prosperity and international credibility as a leader of the global climate change agenda.[7]

This last point regarding the economic recovery is an important co-benefit and can perhaps provide a common link between the outlook expressed in President Trump's and President Biden's security strategies, and thus generate unified support for action across the political spectrum.

Talking specifically about the defense budget, President Biden also emphasizes an opportunity to tackle climate change through prioritizing "…defense investments in climate resiliency and clean energy."[8] The strategy returns to the theme of technology playing a critical role in addressing the climate crisis with an intent to invest in technology research and clean technologies.[9] Furthermore:

> …we will support the accelerated growth in renewable energy deployment, invest in climate friendly infrastructure, build resilience to climate change, modernize our energy grid, and provide the international leadership required to encourage countries around the world to do the same.[10]

President Biden's approach is focused on using technology and international cooperation to address climate change. Before proceeding with details on the role of technology, some background material (scientific basis) will provide a foundation on why climate change is now considered a pressing national security issue to be addressed with this multi-prong approach.

Terminology

Climate encompasses long-term weather patterns. Sometimes this is simplified as long-term averages of weather conditions, such as the average high temperature for June at West Point, New York. Climate is best thought of more broadly as a description of the long-term weather patterns (including associated parameters, such as temperature, moisture, cloud-cover, pressure, etc). As for the term "climate change": it provides a more accurate description of environmental changes than "global warming" since temperature change is just one aspect of current and projected fluctuations.

How is the Climate Changing?

In August 2021, the Intergovernmental Panel for Climate Change (IPCC) released their Sixth Assessment Report (AR6) Climate Change: The Physical Science Basis, which provides a baseline for describing the current state of climate change.[11] The last full IPCC report (AR5) from 2014 will also be referenced since the components of the AR6 report are still forthcoming that will address impacts, mitigation, and an overall synthesis. The synthesis report for AR6 is scheduled for release in 2022. [12] [13] For another perspective, the report also references a 2019 assessment of the climate, as published by the American Meteorological Society.[14]

The 2021 IPCC report on the physical science basis includes a Summary for Policymakers, which provides a concise bottom line regarding observed climate change:

> It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred.[15]

This overarching statement from the IPCC identifies the broad changes to the climate and environment with a high degree of certainty. They use the term "unequivocal" to describe this warming. The data and analysis to back this up are detailed in the full IPCC report. We next look at some details on these observed environmental changes.

Surface Temperatures: The 2021 IPCC report indicates that global surface temperatures have increased .99 degrees Celsius from 1850-1900 to the beginning decades of the 21st century, which is about a .19 °C increase from the 2014 AR5 report. Also, these increases are greater over land (1.59 °C) than over oceans (.88 °C)[16] Figure 1 highlights the observed increase in surface temperature (orange) and compares it to a simulated trend without human causes (teal). Furthermore, the left side of the figure puts this change in perspective relative to the reconstructed record in the last 2000+ years.[17]

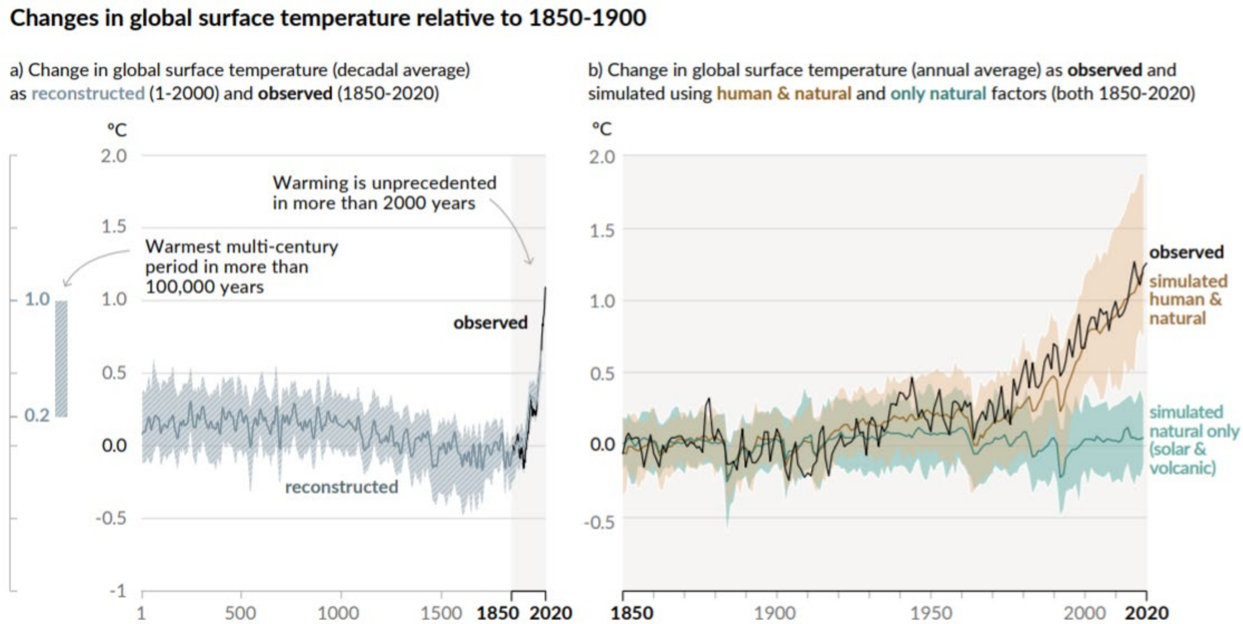

Figure 1:

"Panel a): Changes in global surface temperature reconstructed from paleoclimate archives (solid grey line, 1–2000) and from direct observations. (solid black line, 1850–2020)" [IPCC, 2021]

"Panel b): Changes in global surface temperature over the past 170 years (black line)" [IPCC, 2021]

Sea Level Change: With a warming climate, sea levels are expected to rise since fresh water frozen on the continents will melt and add to the volume of the ocean, raising the globally averaged sea level. A second effect is the expansion of the ocean as the ocean temperature rises; this will also lead to a sea level rise. In fact, thermal expansion accounts for 50% of the rise in sea levels from 1971-2018 and 22% of the rise is attributed to melting glaciers.[18] An increase of .20 meters in global sea levels has been observed from 1901 to 2018, with "Human influence was very likely the main driver of these increases since at least 1971."[19] Figure 2 (from the 2014 IPCC report) depicts the global sea level rise, with multiple data sets indicating this development.[20]

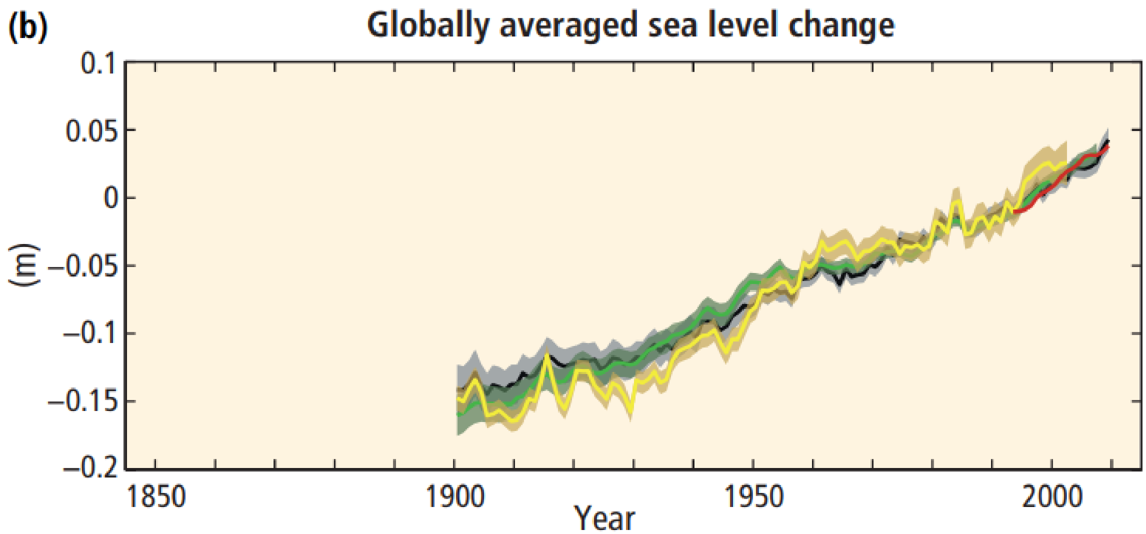

Figure 2: "Annually and globally averaged sea level change relative to the average over the period 1986 to 2005 in the longest-running dataset." [IPCC, 2014]

Ocean Acidification: The cause of these changes is described below, but a major contribution is the burning of fossil fuels, which adds carbon dioxide (CO_2) to the atmosphere. Some of this atmospheric CO_2 is absorbed into the oceans. This absorption of CO_2 increases the acidity of the ocean since as CO_2 dissolves in water carbonic acid is formed, which lowers the pH of the ocean over time.[21] 2021 IPCC reports notes that "It is *virtually certain* that human-caused CO2 emissions are the main driver of current global acidification of the surface open ocean."[22] Why is ocean acidification relevant or perhaps concerning? Acidification impacts organisms with hard shells that depend on carbonate ions in the water to build their shells, etc. As the pH decreases (due to more dissolved CO_2) more of these carbonate ions are bonded with hydrogen ions in the water reducing carbonate ions available for organisms to build their shells/skeletal material.[23] Evidence of the ocean absorbing CO_2 was highlighted by the Sabine et. al. study, which the ocean absorbs about 48% of emissions from fossil fuels and cement manufacturing from 1800-1994, which was estimated at on-third of the potential storage at the time of the study.[24]

Glaciers/Ice Sheets: As indicated in the sea level change discussion, melting of ice on land is a logical additional impact. It is "*very likely* that human influence has contributed to the observed surface melting of the Greenland Ice Sheet…", while there is less evidence of a similar influence in Antarctica.[25] In recent news, rain was reported in Greenland at the National Science Foundation's Summit Station. This was the first report of rainfall at this location, which is at 3,216 meters elevation.[26] These warm conditions contributed to mid-August having seven times the average surface mass loss; large areas of bare ice along coastal areas late in the season will contribute to surface runoff into the ocean instead of being absorbed.[27] This recent example highlights the general trend outlined in the IPCC report, although you should be cautious drawing conclusions from a single report in the news. For example, early summer snowfall helped minimize the impact of melting events in Greenland by reducing runoff and protecting bare ice.[28] In the end, this just may have helped mitigate melting, but glaciers are a balance between accumulation and melting, so snowfall amounts must also be considered.

Arctic Sea-Ice: With high confidence from 2011-2020 "annual average Arctic sea ice area reached its lowest level since at least 1850."[29] A recent (June 2021) study by Shuyao et. al. investigated causes for the decline in Arctic Sea ice late in the fall. It is no surprise that surface air temperature showed the highest correlation with reduced sea ice extend, but higher specific humidity as well as anomalously low pressure over the central Arctic were also associated with reduced sea ice extend.[30] One can easily conceptualize some negative impacts from this change, such as impacting habitat for wildlife, but are there some positive aspects of decreasing sea ice? How could this impact shipping and trading routes? Could shorter routes lead to less greenhouse gas emissions from cargo ships?

You may note that a number of these effects are clearly related. The Earth system is complex, but you can draw some basic conclusions based on these broad trends. For example, you could expect some positive feedback from the decrease in sea-ice and ice sheets. Ice is more reflective than land or ocean water, so it will reflect more of the incoming solar radiation back to space keeping the climate cooler than if the ice was not present. As the amount of ice decreases, it is reasonable to expect more solar radiation to be absorbed, and more ice melts, which allows more solar radiation to be absorbed, etc. Of course, some non-linear effects can play a role, such as impacts on cloud cover, but this simple relationship can provide insight into a possible trajectory of continued warming.

Providing another assessment on the state of climate change, the following American Meteorological Society assessment describes global conditions as of 2019:

> The year 2019 was among the three warmest years since records began in the mid-to-late 1800s. Only 2016, and for some datasets 2015, were warmer than 2019; all years after 2013 have been warmer than all others back to the mid-1800s. Each decade since 1980 has been successively warmer than the preceding decade, with the most recent (2010–19) being around 0.2°C warmer than the previous (2000–09).[31]

In more recent news, July 2021 was declared "Earth's hottest month on record", by the National Oceanic and Atmospheric Administration (NOAA).[32] The global surface temperature (land and water) for July 2021 was .93°C above the average for the 20th century, which is the hottest in the 142-year climate record. Also, land-surface temperatures over North America were 1.54°C above the average, breaking a July record last set in 2012. Finally, it is likely that 2021 will be among the top 10 warmest years on record.[33]

What is Causing the Climate to Change?

In describing the cause of climate change, an important factor is technology, which may also combat and help us adapt to climate change. The 2014 IPCC report summarizes this cause, again with high confidence:

> Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century.[34]

This trend has not changed with the 2021 IPCC report, which notes that "In 2019, atmospheric CO2 concentrations were higher than at any time in at least 2 million years (high confidence), and concentrations of CH4 and N2O were higher than at any time in at least 800,000 years (very high confidence)."[35]

Direct evidence of the increase in greenhouse gases (carbon dioxide, nitrous oxide, methane) is available from atmospheric measurements (lines) and ice cores (dots), as depicted in Figure 3.[36]

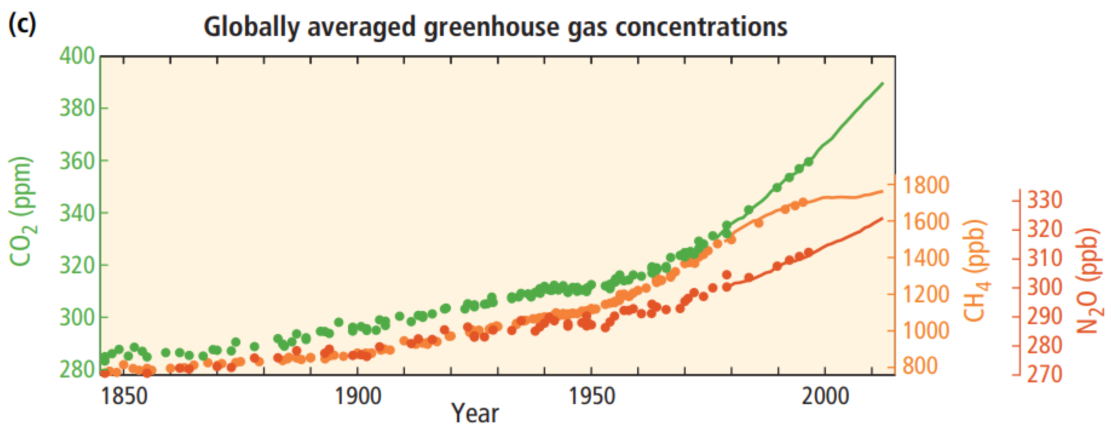

Figure 3: "Atmospheric concentrations of the greenhouse gases carbon dioxide (CO2, green), methane (CH4, orange) and nitrous oxide (N2O, red) determined from ice core data (dots) and from direct atmospheric measurements (lines)." [IPCC]

There is some uncertainty as to the exact amount of emissions, but Figure 4 depicts sources of CO_2 dating back to the 1850s.[37]

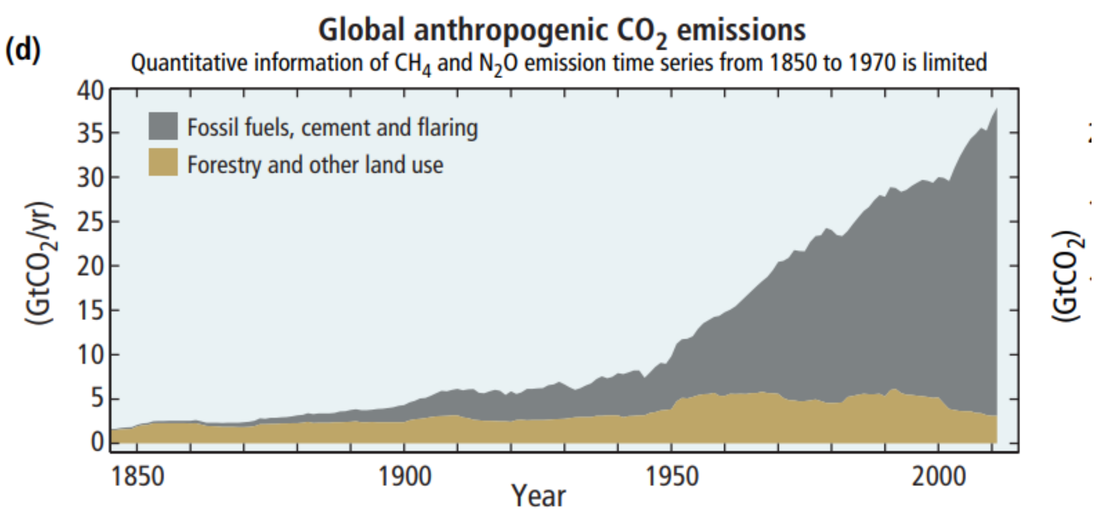

Figure 4: "Global anthropogenic CO2 emissions from forestry and other land use as well as from burning of fossil fuel, cement production and flaring." [IPCC]

Why do greenhouse gases lead to warming? Greenhouse gases (and the greenhouse effect), which include water vapor, are essential for maintaining a habitable climate. You can think of the climate system in an energy balance with solar energy as the input and infrared radiation leaving the Earth and atmosphere as the output. Greenhouse gases preferentially absorb the outgoing infrared radiation emitted from the Earth while letting the incoming solar radiation pass through. Thus, the greenhouse gases keep some energy in the atmosphere that would otherwise be lost to space, warming the atmosphere and surface below. If there is an overall balance between incoming and outgoing energy, the climate can remain consistent. If the concentration of greenhouse gases increases, more of the outgoing radiation is absorbed and a warmer climate is expected (in the simplest model).

Clearly this climate change was driven by human causes, particularly by technology. For example, industry and transportation contribute to CO_2 emissions. To reduce these emissions, we need to change the source of energy for this technology and/or capture the carbon released through the burning of fossil fuels.

The global COVID-19 pandemic provided an opportunity to study the impact of reducing our CO_2 emissions. Andreoni estimates that a -12.1% reduction in CO_2 emissions in the first half of 2020 due to the COVID-19 pandemic.[38] Dacre et. al. built a statistical model using numerical weather prediction and observational data from the UK and Ireland to investigate how changes in emissions would impact CO_2 concentrations. They found a sizeable lag between changes in emissions and CO_2 concentration trends, suggesting that even if global action to reduce greenhouse gas emissions happens now, we can expect some time before these changes impact the environment and thus climate change (perhaps several years).[39]

How will the Climate Change in the Future?

We have briefly examined how the climate has changed since the Industrial Age. Will these trends continue? How certain are we of future predictions? How will changes in carbon emissions affect the current trends? Would the drastic reduction of man-made carbon emissions be enough to prevent significant climate change or do we also need to sequester or capture carbon from the Earth system? The paper will touch on some of these issues, but this should highlight the role of technology and policy decisions in dealing with anticipated changes.

If one is developing U.S. or global policy on climate change the 2014 IPCC statement about the future changes in climate is useful:

> Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks.[40]

The updated statement from the 2021 IPCC report, strikes a similar tone with more specific numbers, although this statement does not include an assessment of impacts:

> Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO2 and other greenhouse gas emissions occur in the coming decades.[41]

The IPCC statements should be taken as a call to action to minimize impacts from climate change. Further, it is not an all or none scenario. Taking some nontrivial action to minimize climate change is arguable better than no action, even if truly drastic action is required to make a significant impact. For example, the 2014 IPCC report highlights that "The risks of abrupt or irreversible changes increase as the magnitude of the warming increases."[42] This suggests that it is better to do what we can to combat climate change, instead of throwing our hands up in dismay.

An overarching theme for addressing climate change can be finding win-win scenarios. Technology can help the US (and other nations) make necessary changes without a dramatic alteration in lifestyle. Riding a bike to work does limit greenhouse gas emissions but is it realistic to expect an entire developed nation to give up automobiles willingly? Electric cars, powered by green energy is likely an easier sell – and more logical solution -- for most people in the U.S.

How Does Climate Change Impact the US Military?

The National Defense Authorization Act in 2018 directed an assessment of DoD vulnerabilities to climate change.[43] This report provides insight into potential impact to DoD installations and DoD operations as well as mitigation strategies.

The report examined vulnerabilities of 79 DoD installations to potential impacts from climate change to events including flooding, drought, wildfires, desertification, and thawing permafrost.[44] Recurring flooding (including coastal storm surge and inland flooding) affects the greatest number of installations with 53 of 79 currently impacted and potential for 60 of 79 installations to be impacted.[45] Of note, Joint Base Langley-Eustis in Virginia has experienced an increase in frequency and severity of flooding due to a 14-inch increase in sea level of since 1930, with some of that due to land subsidence (sinking).[46] Of note, land subsidence is not directly related to climate change but can compound effects of rising sea levels due to climate change. Thawing permafrost is only a concern for one installation, Fort Greeley, Alaska, but could significantly impact training by increasing the extent of wetlands and making the terrain less trafficable.[47] These are just a few examples of potential impacts. Clearly installations in the Western U.S. need to be increasingly concerned about desertification and wildfires, amplified by the severe drought as of June 2021 covering much of the Western U.S., with reservoirs at about half normal levels in California.[48]

Beyond impacts to military installations, the DoD report also highlights potential impacts to DoD operations, which are likely to expand in number due to changes in climate.[49] The geopolitical consequences are alluded to by Chairman of the Joint Chiefs of Staff, General Dunsford in 2018:

> When I look at climate change, it's in the category of sources of conflict around the world and things we'd have to respond to. So it can be great devastation requiring humanitarian assistance — disaster relief — which the U.S. military certainly conducts routinely.[50]

What is the Role of Technology in Combatting Climate Change?

<u>Cement:</u>

There are myriad examples of how technology can help us combat climate change. Obvious examples are changes in energy production and energy use, but this paper starts with a less obvious contribution to climate change: cement.

Chatham House conducted a report on this topic in 2018 entitled "Making Concrete Change: Innovation in Low-carbon Cement and Concrete." Their report highlights that cement (the critical component of concrete) is responsible for 8% of global CO_2 emissions, more than 4 billion tons per year.[51] The report focuses on technology to reduce CO_2 emissions despite a growing demand for cement. While noting that reductions can be gained from improvements in energy efficiency, alternative energy and capturing/storing carbon, the report focuses on the more disruptive/transformative technology solution of the "potential to blend clinker with alternative materials, and on the use of 'novel cements'."[52] "Clinker" is the intermediate cement component produced with a kiln. There is significant potential for innovation here since:

> Clinker substitution is not only a very effective solution, but also one that can be deployed cheaply today, as it does not generally require investments in new equipment or changes in fuel sources. It is, therefore, especially important to scale up clinker substitution in the near term while more radical options, such as the introduction of novel and carbon-negative cements, are still under development.[53]

One example of this material solution to reducing the carbon emission from cement is the startup BioMason, which uses bacteria to produce bio-concrete, similar to the process of growing coral.[54] CEO Ginger Krieg Dosier developed a process that produces a cement alternative "…at room temperature, without the need for fossil fuels or calcination – two of the main sources of the cement industry's CO_2 emissions."[55] Instead of releasing CO_2 into the atmosphere this technique actually removes CO_2 from the air.

Another innovative technique for reducing the carbon impact of cement was developed by the Nationwide Engineering and the University of Manchester. They are adding graphene to concrete, which makes the material 30% stronger and will reduce the use of material, and thus carbon emissions.[56] Graphene is a material made from a layer of carbon. This could provide cost savings without requiring new equipment, so it could be easy to implement.[57] Approaches like this are particularly appealing since they can reduce carbon emissions, potentially reduce production costs, and do not require an overhaul in production processes/equipment. In other words, this could be a win-win for industry and combating climate change.

Energy Industry:

A logical place to look for technology to address climate change is in the energy industry. Can we generate sufficient energy to run our economy without continuing to burn fossil fuels? Does nuclear energy play a role in reducing carbon emissions? Policy decisions also interplay with the opportunities that technology provides. Should the US subsidize renewable energy and/or nuclear energy to encourage a transformation away from fossil fuels? Should the U.S. introduce disincentives to burn fossil fuels (at least without capturing the carbon), in the form of a carbon tax or cap-and-trade scheme? A few areas of the energy industry will be examined to provide further insight for discussion.

Solar Power:

A natural application of technology to combat climate change is harnessing energy without relying on fossil fuels and the associated carbon emissions. Global solar power generation has jumped from 20 gigawatts to 600 gigawatts in 10 years as of the end of 2019.[58] The most common solar cells are made from silicon, which convert 17-19% of the sun's energy, a 10% increase over 10 years, but with a theoretical limit of 30% efficiency.[59] The cost of photovoltaics have continued to drop, allowing them to compete or outcompete with fossil fuel power generation.[60] Cost per megawatt hour has dropped from about $350 in 2009 to about $40 in 2020.[61] Not surprisingly, there is huge growth in the photovoltaics market with a four-fold increase in installation of photovoltaics in the 9 years leading up to 2011, with continued growth expected, mostly outside of North America and Europe.[62]

Technology could help continue the trend of harvesting solar power past the limitation of photovoltaics mentioned previously. One promising technology is perovskites, which uses a crystal structure to absorb sunlight and can be applied inexpensively in a thin coating on many surfaces.[63] A Swiss startup, Insolight, takes another approach by concentrating solar energy using a grid of lenses embedded in a solar panel, with a model achieving 29% efficiency, with the possibility of 32%.[64]

There are some obvious limitations of solar power, regardless of how cheap and efficient it becomes. It is limited to hours of sunlight, which can be affected by cloud cover and seasonal effects in solar intensity. Some economic areas will be more favorable for solar power, but as costs go down relative to carbon generated power, the utilization of solar power will likely increase for economic reasons (regardless of climate change). Clearly solar must be supplemented by other power sources to provide a true replacement for fossil fuel power generation. Can we effectively and efficiently store power collected during the day? What other reliable sources of power generation can augment solar power?

Battery Technology:

Battery technology can play a number of roles in transitioning away from carbon-based energy (from power generation to transportation and beyond). When used in conjunction with intermittent renewal energy sources such as solar or wind, it can store and provide a reliable source of power. But is it cost affective as a replacement for carbon-based power generation? The trend is promising for lithium ion batteries, with a steep drop in the cost of battery storage to $132 per megawatt-hour in 2020, which allows it to compete with other sources of peak-demand generation.[65] The cost of the lithium-ion batteries also is dropping from the current $1,191 per kilowatt hour to a projected $100 per kilowatt hour in 2023.[66] Despite drops in cost, lithium-ion batteries do have limitations, such as a limited lifespan with drops to 70-90% of capacity in five years with high use.[67] Another downside is resource demands from cobalt mining, which could have environmental considerations in places such as the Democratic Republic of Congo, with over 55% of cobalt reserves.[68] Another drawback is the safety risk from ethylene carbonate, which is flammable and can release toxic gases if burned.[69]

A potential disruptive technology to move past the limitations of lithium-ion batteries is solid state batteries.[70] Researchers at The University of Texas at Austin developed a solid-state battery cell with at least three-times greater energy density than lithium-ion batteries, without the risk of combustion, long life, and fast charging. The risk associated with lithium-ion batteries is due to metallic dendrites that can form in the liquid electrodes, causing a short-circuit and possible fire.[71] Other advantages include the ability to operate below 60 degrees Celsius and using sodium instead of lithium.[72] The long life is demonstrated by cycling in excess of 250 times with no loss in energy density.[73] All of this sounds promising but costs could be high in the initial development, "in the range of ~$800/KWh to ~$400kWh by the year 2026", so it is likely to target premium vehicles.[74] Consumer demand for electric vehicles as well as investment from government could drive down the cost of solid state batteries in the future and is a relevant policy question. Ariel Cohen from Forbes argues that "President Biden would be wise to invest in research, but government labs should not pick winners in tech – unless it is for military applications."[75]

Nuclear Power:

The International Energy Agency's 2019 report on Nuclear Power in a Clean Energy System provides an overview of the role that nuclear power can play in fighting climate change. The report highlights that nuclear power is on the decline at a time when there is a need to reduce carbon emissions. In the 50 years prior to this report, CO_2 emissions were reduced by more than 60 gigatons, which is almost two years' equivalent of global energy emissions.[76] The report points out how nuclear makes it easier to meet climate change goals and recommends government work to extend the life of current facilities, support new construction, and support the development of new technology.[77]

One potential for technology innovation is the development of Advance Small Modular Reactors (SMRs), which the U.S. Office of Nuclear Energy points out as a "key part of the Department's goal to develop safe, clean, and affordable nuclear power options."[78] Advantages of SMRs include modularity, which reduces the time for construction and the cost for investment, allows for incremental increases in energy demand, augments safety and security, stimulates job growth, and more.[79] This SMR technology appears to be a promising approach but as noted it is still in development. The U.S. could influence the development of this technology through investment as well as reducing regulatory hurdles.

Globally, nuclear power could face opposition because of safety concerns from mishaps such as the Fukushima disaster in Japan. For example, Germany has decided to phase out nuclear energy, which has already begun and is set to complete in 2022.[80] A 2019 study from the National Bureau of Economic Research found that this shift from nuclear energy in Germany was mostly replaced with coal power generation, which has a social cost of 12 billion dollars per year, with more than 70% of this cost coming from mortality risk from air pollution.[81] This highlights a potential co-benefit of addressing climate change in general. Reduction of carbon emission from coal power generation and other polluting fossil fuel combustion could have significant health benefits and thus economic benefits in and of itself. Even if you were not concerned about climate change you could still argue in favor of moving away from fossil fuels for economic and health reasons.

<u>Carbon Capture:</u>

We continue to rely on fossil fuels for energy production and industry. However promising green energy technology, it would take time to replace fossil fuels outright. Can we continue to burn fossil fuels while still minimizing the impact to climate change? Can technology also play a role in capturing carbon emissions?

The National Energy Technology Laboratory (NETL) is investigating three applications of technology related to carbon capture.[82]

1) One approach is working with Technology Centre Mongstad in Norway to test four different processes to capture carbon from CO_2 emitted during power generation and refining oil.[83] Removing CO_2 has proved challenging since it is only 4% of 4-15% of the gas emitted during power generation, but the Stanford Research Institute has a promising technology that can operate at room temperature, uses cheap salt solutions, and has a higher capacity than earlier processes.[84]
2) Another approach ties back to cement; NETL is working with UCLA on cement produced from coal or natural gas emissions, with a test capturing 75% of CO_2.[85]
3) A third approach of NETL, in collaboration with the Great Plains Institute, uses pipelines to transport CO_2 and then employs existing techniques from the oil and gas industry to inject CO_2 into the ground where it can be stored under layers of nonporous rock.[86] Policy is also relevant to this application, since a tax credit was approved by Congress in 2018 for using recovered CO_2 to extract oil underground.[87]

Should the U.S. find more ways to incentivize industry to capture carbon? What are some policy approaches that might be effective in developing these technologies?

How does Climate Change Affect U.S. Policy?

Clearly climate change is a global issue and is ripe for global cooperation and certainly national cooperation. The IPCC report highlights that: "Because climate change has the characteristics of a collective action problem at the global scale…effective mitigation will not be achieved if individual agents advance their own interests independently, even though mitigation can also have local co-benefits."[88] The nature of this problem has led to international agreements such as The Paris Agreement, a legally binding agreement, which sets a goal of limiting warming to less than 1.5 degrees Celsius above pre-industrial age temperatures.[89] The IPCC statement also suggests that taking action to combat climate change can also have co-benefits, so U.S. policy to combat climate change could have other payoffs that make it worthwhile, independent of addressing climate change. For example, replacing coal with nuclear power can also increase energy security, reduce health impacts from air pollution, and reduce accidents from coal mining (along with potential negative impacts).[90]

Although the U.S. was the only country to withdraw from The Paris Agreement under the direction of President Trump on 4 November 2020, Washington rejoined the agreement on 19 February 2021 under President Biden.[91] The Paris Agreement accounts for the role of technology in dealing with climate change in Article 10, which focuses on developing and sharing technology "…to improve resilience to climate change and to reduce greenhouse gas emissions."[92]

Discussion Questions

Here are some additional questions to prompt discussion and analysis:

Should the U.S. collaborate with other nations to address climate change? If yes, to what extent?

What are some effective policy approaches that would enable technology to address the problem of climate change?

What are some examples of benefits in other areas (economic, health, etc.) that would be gained by addressing climate change?

How is climate change relevant to the interests and missions of the DoD?

What are some ways to bridge the political divide, both globally and domestically, in addressing climate change? What approaches could garner bipartisan support at home?

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Sea Level Rise Viewer (NOAA): https://coast.noaa.gov/slr/

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