ON THINNING ICE

IMPLICATIONS OF CLIMATE CHANGE FOR NATIONAL SECURITY

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ABOUT THE CENTER FOR STRATEGIC AND BUDGETARY ASSESSMENTS (CSBA)

The Center for Strategic and Budgetary Assessments is an independent, nonpartisan policy research institute established to promote innovative thinking and debate about national security strategy and investment options. CSBA's analysis focuses on key questions related to existing and emerging threats to U.S. national security, and its goal is to enable policymakers to make informed decisions on matters of strategy, security policy, and resource allocation.

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CHAPTER 1

Thinking About Climate Change and Security

Introduction

Climate change is a matter of ever-growing global concern. Numerous studies and reports sponsored or done by, e.g., the United Nations, the United States government, governments of other nations, and a wide range of other research institutions have pointed out with increasing urgency the devastating potential impacts of climate change if no action is taken by the international community to fully implement the 2015 Paris Accords in order to limit and mitigate those impacts. Climate action was a specific issue addressed in the G7's June 2022 meeting final communique.

Despite the global attention to this issue, there has not been sufficient research conducted on this issue in Japan.[1] The Center for Strategic and Budgetary Assessments (CSBA) has therefore undertaken a short study of potential impacts of climate change as they could affect Japanese national security. The purpose of the study is to suggest ways of framing how to think about the many complex and varied potential implications of climate change if the projections and conclusions reached in major studies by multiple international organizations over recent decades prove to be accurate.

CSBA will use the International Energy Agency's *Net Zero by 2050: A Roadmap for the Global Energy Sector* (hereafter referred to as *Net Zero 2050*) study as the reference document for this report, and to assume that the major projections and conclusions of the study are valid.[2] This report will then suggest and assess various kinds of impacts affecting security issues that could follow logically if those in fact turn out to be accurate by 2050.

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[1] Y. Kameyama & K. Ono, "The development of climate security discourse in Japan," *Sustainability Science*, 16, no.1 (2021): 271–281, https://www.researchgate.net/publication/345483220_The_development_of_climate_security_discourse_in_Japan.

[2] CSBA researchers will not seek to assess the validity or accuracy of various conclusions reached by climatological experts or organizations as reported in key documents such as *Net Zero 2050* or studies by the Intergovernmental Panel on Climate Change (IPCC) since doing so falls outside of CSBA's recognized areas of expertise. The authors will use such conclusions solely as the basis to explore their security implications if those prove accurate.

This report will focus on:

- Key changes in the future security environment associated with climate change;
- Diverse consequences for national security of such change; and
- Implications for changing or expanded demands on military, coast guard, and other security forces.

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Based on the analysis in *Net Zero 2050*, the world as a whole faces daunting security challenges posed by the projected effects of climate change. Many experts believe climate change will become the single most important issue that will shape the national security agenda of the 21st century. Thus, with certain exceptions, this report's findings will concern issues that many countries besides Japan, especially those with coastlines, will need to address over the coming decades if the *Net Zero 2050* findings and projections came to pass.

Multiple international and national organizations and authorities have issued reports on the potential implications of a warming climate on a wide range of matters involving the security of the world's nations. It will almost certainly exacerbate existing tensions over competition for natural resources; contribute to internal instability in some countries; impact investment requirements; and affect the future trajectory of technological adaptation, particularly with regard to energy technologies needed to move away from fossil fuels to achieve "net zero emissions" (NZE) by 2050. These implications potentially could have significant direct consequences for national security in multiple, possibly unanticipated, ways.

In the United States and other countries, the interconnection between climate change and national security has become increasingly accepted over the past decade by both policymakers and defense planners.[3] That said, the complexity and scope of that interconnection means that there are multifarious ways to approach it analytically. This report will suggest one initial framework for thinking about this complex matter and its various challenges and implications.

Climate Agreements and Global Temperature Goals[4]

On December 12, 2015, 196 countries adopted the Paris Agreement, a legally binding treaty on climate change.[5] For the first time a global goal to limit temperature rise was established at "well below 2°C above pre-industrial levels," with signatories also agreeing to pursue efforts that would limit global

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[3] See National Research Council, *National Security Implications of Climate Change for U.S. Naval Forces: Letter Report*, (Washington, DC: The National Academies Press, 2010); Office of the Director of National Intelligence (ODNI), *Global Water Security* (Washington, DC: Director of National Intelligence, 2012); The White House, *Findings from Select Federal Reports: The National Security Implications of a Changing Climate,* May 2015, https://obamawhitehouse.archives.gov/sites/default/files/docs/National_Security_Implications_of_Changing_Climate_Final_051915.pdf; Office of the Under Secretary of Defense (OUSD) for Acquisition and Sustainment, *Report on Effects of a Changing Climate to the Department of Defense* (Washington, DC: OUSD for Acquisition and Sustainment, 2019); "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021); Department of Defense, Office of the Undersecretary for Policy (Strategy, Plans, and Capabilities), 2021, *Department of Defense Climate Risk Analysis,* Report Submitted to National Security Council; and Department of the Army, *United States Army Climate Strategy* (Washington, DC: Office of the Assistant Secretary of the Army for Installations, Energy, and Environment, February 2022).

[4] For purposes of this study, the term "temperature" will refer to "global *surface* temperature."

[5] "The Paris Agreement," *United Nations Framework Convention on Climate Change,* 2022, https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

mean surface temperature rise to 1.5°C by 2100.[6] [7] Since then, while momentum continues to grow towards even more ambitious emission reduction targets, current national pledges remain insufficient, only covering roughly 70 percent of global CO_2 emissions (consistent with an mean global temperature rise of 2.1°C by 2100).[8] [9] On the current trajectory, mean global temperature rise is expected to reach 1.5°C around 2030, and surpass 2°C by about 2050, with most of the growth coming from emerging and developing economies.[10] As global surface temperatures continue to rise, countries can expect to experience the increasing physical effects of climate change that will serve to exacerbate existing tensions in the political, economic, and military spheres. As countries continue to combat climate change, the world will see the emergence of rapid and far-reaching transitions from fossil fuels and technological developments that will affect different economic and societal sectors as well as different countries in diverse ways, including the impacts on national security more generally.

Several key studies have examined the impacts of future climate change and the policies and technologies that will need to emerge to mitigate those impacts. In May 2021, the International Energy Agency (IEA) released its report *Net Zero by 2050: A Roadmap for the Global Energy Sector,* which provided a comprehensive study on how the world can transition to a net zero emissions system by the year 2050.[11] This study laid out an assessment of what a cost-effective and economically productive path toward net zero emissions would entail.[12] The most recent (2018) quadrennial United Nations Intergovernmental Panel on Climate Change (IPCC) special report on the impacts of global warming of 1.5°C highlighted the importance of reaching Net Zero CO_2 emissions globally by 2050 or sooner to avoid the worst effects of climate change. The report also offered a comparison between the impacts of global warming of 1.5°C and of 2°C, respectively, warning that the latter would lead to significantly worse consequences.[13] A 2021 U.S. National Intelligence Council (NIC) National Intelligence Estimate (NIE) also compared the effects from those two temperature rises. (See Figure 1.)

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[6] "Paris Agreement," *Report of the Conference of the Parties to the United Nations Framework Convention on Climate Change*, 21st Session, 2015: Paris, Article 14, subsection 2.

[7] The term "pre-industrial levels" refers to the period prior to the onset of large-scale industrial activity, occurring around 1750. The reference period for approximating global mean surface temperature is from 1850-1900. See Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018), p. 556.

[8] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. i; Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021), p. 13.

[9] Climate change science and modeling has been a cornerstone in generating projections and quantifying the uncertainty of the trajectory of future temperature rise and the physical effects of climate change. Confidence in the model estimates have advanced over recent years, but slight differences in outputs still occur. See David A. Randall, Richard A. Wood, Sandrine Bony, Robert Colman, Thierry Fichefet et al, "Climate Models and Their Evaluation," In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC (FAR)*, (Cambridge, UK: Cambridge University Press, 2007), p. 591.

[10] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Changeand_National_Security.pdf, p. i, 1; Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021), p. 36.

[11] Note that the IEA report is concerned solely with emissions of CO_2 and not other greenhouse gases.

[12] Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021).

[13] Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018).

1.5°C versus 2°C Temperature Rise

The Paris Agreement signatory countries undertook a pledge to limit global warming to well below 2°C while also pursuing efforts to limit warming to 1.5°C by 2100. Depending on the actions nations take between now and 2050, the risks and physical effects of climate change accompanying the two temperature boundaries could vary significantly. Some scientists have argued that as mean global temperature continues to rise, the associated risks will compound, even becoming uncertain and potentially catastrophic above 2°C.[14]

FIGURE 1: NATIONAL INTELLIGENCE COUNCIL (NIC) AND IPCC FORECASTS OF THE EFFECTS OF CLIMATE CHANGE AT 1.5°C AND 2°C

Physical Effects of Climate Change	1.5°C	2°C	Impacts to Human Security
Precipitation: Increased frequency of extremes over land	NIC NIE: 17%	NIC NIE: 37% (2.18x worse)	Will lead to economic losses, increased calls for humanitarian assistance
Heat Waves: Global population exposed to severe heat at least once every five years	NIC NIE: 14%	NIC NIE: 37% (2.6x worse)	Reduce labor productivity, increase frequency and intensity of wildfires
Droughts: More people exposed to severe droughts	NIC NIE: Around 132 million	NIC NIE: Around 194 million (1.47x worse)	Undermine food security in developing countries, cause more extreme wildfires, increase political instability, drive migration
Sea Level Rise	IPCC: By 2100, 0.40 meters	IPCC: By 2100, 0.46 meters (1.15x worse)	Increasingly place coastal cities as risk and exacerbate storm surges that damage infrastructure
Arctic Ice-Free Summers: Number of ice-free summers	IPCC: At least one every 100 years	IPCC: At least one every 10 years (10x worse)	Threaten ocean circulation and salinity, local ecosystems, and increase competition over resources and transit route access
Food Security: More people exposed to lower yields	IPCC: 32-36 million	IPCC: 330-396 million (Mean: 10.7x worse)	Crop failures can lead to extreme food price spikes, hunger, and famine
Water Scarcity: More people exposed to water stress	IPCC: 4%	IPCC: 8% (2x worse)	Transboundary tensions will likely increase over shared water sources, triggering new water insecurity in numerous parts of the world

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[14] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. i.

Fisheries: Decline in Marine Fisheries	IPCC: 1.5 million tons	IPCC: 3 million tons (2x worse)	Drive marine species to higher latitudes; drive the loss of coastal resources; reduce the productivity of fisheries and aquaculture

Source: "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021); and Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018).

Despite the ostensibly small – but in fact very significant – half-a-degree temperature difference, a simple increase of 0.5°C in mean global temperatures can lead to serious, lasting effects. The magnitude of these risks depends on multiple factors, including the rate of global warming, geographic location, a country's level of development, and human responses to mitigation efforts.[15] Even if greenhouse gas emissions were sufficiently reduced to meet the 1.5C goal by 2050, geopolitical tensions are still likely to increase markedly as nations compete to control key energy resources and to dominate new technologies that may emerge during the transition to clean energy.[16]

Assumptions and Definitions

This report is an analytic study that assesses potential impacts on selected aspects of future national security issues that Japan and countries around the world may face as a result of climate change. For this report, CSBA accepts for purposes of argument the major assumptions concerning climate change that were made in the above-mentioned reports and assesses the security implications that would derive logically from those key assumptions should they prove true in future years. Specifically, the following assumptions from the scenario utilized in the IEA *Net Zero 2050* report are assumed to be true:[17]

- All countries will cooperate towards achieving Net Zero emissions worldwide (while also recognizing the different economic stages of development in countries);
- The countries that may not cooperate towards Net Zero emissions may be offset by corresponding adaptation measures from the other countries;
- There will be an orderly transition across the energy sector towards low-carbon emissions and renewable energy sources (including nuclear, wind, solar, and hydropower); and
- A rapid deployment of more energy-efficient technologies, energy storage technologies and the swift growth of renewables will occur and play a central part in reducing emissions.

For purposes of this report, the term "national security" will be considered in its broadest sense. That is, it will comprise a range of possible or potential threats to the country of Japan, its citizens, and its

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[15] Alan Buis, "A Degree of Concern: Why Global Temperatures Matter," *NASA Global Climate Change*, June 19, 2019, https://climate.nasa.gov/news/2865/a-degree-of-concern-why-global-temperatures-matter/.

[16] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. i.

[17] Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021), p. 50-55.

institutions. National security is often thought of primarily in terms of military or violent threats from other states and/or from non-state actors. However, the potential implications stemming from climate change may affect other aspects of security such as economic security (including food security), energy security, disaster relief needs due to severe weather events, and so forth, and thus must also be considered, particularly since military, coast guard, and other kinds of traditional security forces may have significant roles to play in dealing with those kinds of non-military national security concerns.

Reports and studies on climate change have somewhat different perspectives on what defines the nexus between climate change and national security. In recent debates and discussions, most climate researchers speak to the security implications of increasing global mean surface temperatures mainly through the lens of food, economic, and ecological security. A fundamental element missing from these discussions is the effect of climate change on national security in its various dimensions. While food, economic, and ecological issues and implications have their own national security aspects, it is not the entire picture. Scholars and climate scientists would be remiss to exclude other national security implications from the climate change discourse. Issues such as increased instability around the world leading to an outbreak of conflicts, growing geopolitical competition over new and/or vital strategic resources, changes in employment of, and operational requirements for, military, coast guard, and other security forces, and risks to military infrastructure and equipment due to extreme weather events will all play a role in the future climate-impacted security environment and how nations should conceptualize the climate change issue and its challenges.

This report accordingly seeks to go beyond a narrow view of climate security and includes an analysis of potential political, economic, and certain technological impacts of climate change as exacerbators of national security challenges, including with regard to changes in military, coast guard, and other security forces employment and operations. As the climate change issue and challenge evolve over time, this study can hopefully be used as a framework to help policymakers and defense planners think through these issues and their future effects on national security more broadly.

Report Organization

The report consists of five chapters. Chapter 1 introduced the topic of climate change and national security. Chapter 2 explores key changes in the future security environment, including such topics as increased tensions over food and water resources, population migrations, necessary mitigation efforts to address the impact of rising sea levels, adaptation efforts necessary to maintain an economic and technological edge in the transition to far greater reliance on renewable energy sources, and new areas and regions of competition that will emerge as climate change progresses, particularly in the polar regions. Chapter 3 addresses approaches to mitigate the impacts of climate change and the consequently changed future security environment, including for military, coast guard, and other security forces, given likely increased and/or different kinds of employment of those forces. Chapter 4 discusses technologies and measures likely to be necessary to transition away from fossil fuels towards far greater reliance on renewable and other non-fossil fuel energy sources and second- and third-order effects of adopting such technologies. Lastly, Chapter 5 has some final thoughts.

CHAPTER 2

Key Changes in the Future Security Environment

Per Figure 1, the IEA *Net Zero 2050* and the most recent IPCC reports focus heavily on the leading physical effects of climate change and their projected consequences for human populations. They note the physical environmental changes that will drive other consequences. These include more frequent extreme precipitation events (causing large-scale flooding); increases in severe heat waves that will reduce productivity, increase devastating fires, and impact agriculture; and more severe and frequent droughts impacting water security and agriculture. The higher temperatures will see steadily increasing melting of freshwater ice in the polar regions, which would lead to higher sea levels, imperiling low-lying islands and coastal regions, and eventually to routine ice-free periods of varying lengths during summers in the Arctic.

The consequences for human populations will be increased food and water insecurity, with resultant implications for political stability of the most affected countries, potential mass migrations of desperate populations, and new sources of conflict among nation-states over resources. Indeed, competition for resources, some of which may be quite different from those considered most vital today, e.g., oil and natural gas, may become the leading new driver of wars, political instability, humanitarian disasters, and mass population migrations. And the location of the natural resources that may become the most vital in the future – not necessarily the same ones as today – may become a key driver of competition among states, even leading to war, and to significant reordering of important sectors or components of the future global economy.

In some cases, the consequences of climate change will exacerbate already existing problems. Today, the world's land and water resources are even now being exploited at "unprecedented rates," and this can only be expected to worsen as mean global temperatures continue to rise.[18] To mitigate the effects of higher global temperatures that further exacerbate these trends, nations around the world will have to undergo major adaptation efforts, in particular transitioning from the assumed primary contributors

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[18] C. Mbow, C. Rosenzweig, L.G. Barioni, T.G. Benton, M. Herrero et al, "Food Security," in *Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, ed. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Portner et al, (2019).

to global warming, fossil fuels, to renewable energy sources in order to achieve Net Zero emissions (NZE) by 2050.

This transition from fossil fuels to renewable energy will result in significant changes in the key raw material and mineral resources required. There will be "winners and loser" in this shift in energy economics and technology. Certain resources, raw materials, and new technologies will become essential to achieving energy security. At the same time, other resources and technologies essential to today's energy sector will become relatively devalued. These changes will inevitably generate significant political and economic tensions as the energy resource and flow dynamics evolve.

With the polar sea-ice continuing to melt, new summer Arctic sea routes will become accessible, as will significant undersea mineral and energy resources. The availability of such sea routes will have significant economic implications, driven by substantial transportation efficiencies. The opportunity to engage in commerce through these opened trade routes and to stake claims on sea areas rich with newly discovered exploitable natural resources will draw the attention of many competing nations.

Conflict Over Resources

Conflict over resources has several aspects. First, and perhaps most critically, are those resources central to food and water security, with the latter being closely connected with the former. Energy security is similarly important, both as far as it is an important input required for food and water security, and because its lack or insufficiency can be a major factor in inability to relieve mass poverty and/or hunger, which in turn can drive political instability and trigger mass migrations. Lastly, some of the key potential alternative energy approaches and technologies will require new kinds of strategic and raw materials such as rare earth metals and comparatively scarce materials such as, e.g., lithium and cobalt, that are found in regions and countries far different from those associated with today's fossil-fuel-based energy sources. Common to all of these are the likely shifting locations of where key or vital natural energy-related resources are to be found as climate change manifests itself if the trends projected in *the Net Zero 2050* report and other comprehensive studies prove to be accurate.

Food Security

Food production is highly dependent on climate conditions and water supply. Both are fundamental factors affecting future food accessibility. Climate change is already affecting many food resources through rising global temperatures that climatologists argue are driving fluctuating precipitation patterns and a greater frequency of extreme weather events.[19] As the mean global temperature rises, freshwater resources and agricultural yields can be expected to be substantially reduced by the end of the 21st century.[20] Certain geographic locations will feel the effects of climate change on their food and water supply more than others, with the most vulnerable populations located in arid and semi-arid areas, in landlocked countries, and in small island states.[21] Nations located in low-latitude regions will consistently see a negative effect on crop production due to climate change, while those located in

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[19] C. Mbow, C. Rosenzweig, L.G. Barioni, T.G. Benton, M. Herrero et al, "Food Security," in *Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, ed. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Portner et al, (2019), p. 439.

[20] Anil Kumar Misra, "Climate Change and Challenges of Water and Food Security," *International Journal of Sustainable Built Environment* (2014) 3, p. 153.

[21] Vincent Gitz, Alexandre Meybeck, L. Lipper, C. De Young, and S. Braatz, "Climate Change and Food Security: Risks and Responses," *Food and Agriculture Organization of the United Nations (FAO) Report* 110 (2016), p. ix.

higher-latitude regions may see the reverse effect, with more favorable climate conditions for crop production than today.[22] As an illustrative example, climate change already appears to be significantly affecting French wine production.[23]

To keep pace with expected population growth by 2050, food production will need to increase by at least 60 percent.[24] Yet, key agricultural crop yields are set to face net reductions in the future, with climate change already negatively affecting wheat and maize yields in many areas of the world.[25] Today the (climatological) risk of strain on food systems is relatively low but is estimated to rapidly rise to medium risk by 2030 and high risk by 2040.[26]

Asian nations, specifically, have particularly close economic ties to certain climate-dependent sectors, including fisheries. From 2000 to 2019, total world fisheries and aquaculture production exhibited 41 percent growth, with Asian countries accounting for 70 percent of total production in 2019.[27] Today, the Northwest Pacific is one of the most productive areas in the world for fisheries.[28] But as climate change continues to have increasing effects on the world's natural resources, Asia may see a reduction in its total fish production as warming oceans force marine species to higher latitudes. Some forecasts predict a decrease of up to 40 percent of global fish yield in the tropics, with an increase of 30 to even 70 percent in higher-latitude regions.[29]

As certain fish stocks are forced northward, the distribution of stocks within neighboring countries' Exclusive Economic Zones (EEZ) will also shift, ratcheting up transnational tensions over fishing rights.[30] One modeling study shows that by 2030, "23% of transboundary stock will have shifted and 78% of the world's EEZs will have experienced at least one shifting stock."[31] The countries that are reliant on fisheries for food security and/or for their primary economic activity will likely become early

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[22] Vincent Gitz, Alexandre Meybeck, L. Lipper, C. De Young, and S. Braatz, "Climate Change and Food Security: Risks and Responses," *Food and Agriculture Organization of the United Nations (FAO) Report* 110 (2016), p. xi.

[23] Abby Schultz, "How Premier Wine Regions Are Adapting to Climate Change," September 14, 2021, *Barrons*, https://www.barrons.com/articles/how-premier-wine-regions-are-adapting-to-climate-change-01631560565; and Melissa Godin, "The Taste of Bordeaux Is Going to Change," May 22, 2022, *TIME*, https://time.com/5777459/france-wine-climate-change/.

[24] José Graziano Da Silva, "Feeding the World Sustainably," *The United Nations Chronicle*, https://www.un.org/en/chronicle/article/feeding-world-sustainably.

[25] Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018), p. 9; Vincent Gitz, Alexandre Meybeck, L. Lipper, C. De Young, and S. Braatz, "Climate Change and Food Security: Risks and Responses," *Food and Agriculture Organization of the United Nations (FAO) Report* 110 (2016), p. xi.

[26] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 2.

[27] China leads the world in both capture fisheries and aquaculture, accounting for 36 percent of the global share of production in 2019. See Food and Agriculture Organization of the United Nations (FAO), *Statistical Yearbook: World Food and Agriculture 2021*, (Rome, 2021), p. 17-18.

[28] Manuel Barange, Tarub Bahri, Malcolm CM Beveridge, Kevern L. Cochrane, Simon Funge-Smith et al, *Impacts of Climate Change on Fisheries and Aquaculture: Synthesis of Current Knowledge, Adaptation and Mitigation Options,* Food and Agriculture Organization of the United Nations (Rome, 2018), p. 114.

[29] Vincent Gitz, Alexandre Meybeck, L. Lipper, C. De Young, and S. Braatz, "Climate Change and Food Security: Risks and Responses," *Food and Agriculture Organization of the United Nations (FAO) Report* 110 (2016), p. xii.

[30] Juliano Palacios-Abrantes, Thomas L. Frolicher, Gabriel Reygondeau, U. Rashid Sumaila, Allessandro Tagliabue et al, "Timing and Magnitude of Climate-Driven Range Shifts in Transboundary Fish Stocks Challenge Their Management," *Global Change Biology* 28, no. 7, April 2022, p. 2312.

[31] Ibid.

hotspots for regional confrontations. One region of note is the Arctic, an area that is already a source of converging national interests over potential new routes of commerce and newly discovered mineral resources. Future regional disputes between Arctic and non-Arctic states may become intensified as warming ocean temperatures push Bering Sea fish stocks into the Arctic Ocean, leading to new disputes over fishing rights.[32] With the fishing industry already under stress from overfishing, climate change will only serve to hasten the threat of breakdown of commercial fisheries.[33]

Water Security

Food security goes hand in hand with water security. Irrigated agriculture is highly dependent on a reliable water supply, and accounts for about 70 percent of all freshwater utilized by human populations. [34] Climate change and its compounding physical effects will not only affect precipitation patterns, but also global snow and ice melts, hydrological systems, water quality, and overall water availability.[35] Water supply is especially a concern, as areas that historically already receive large amounts of rainfall, e.g., South Asia during monsoon season, will likely face risks of far more frequent and more severe flooding, while areas already prone to less rain will face increased risks of droughts, especially given that the strongest warming is expected to occur at the mid-latitudes during the warm seasons.[36]

Transnational tensions will likely increase over shared water sources, with a high risk of cross-border water tension and conflict by 2040.[37] As rainfall amounts become more unpredictable due to climate change, existing transboundary disputes such as those over the Nile and Mekong Rivers will likely become more difficult to resolve. Egypt already has threatened war over Ethiopian plans to construct a giant hydroelectric dam across the upper Nile River. The Mekong River Basin is an area of rising tensions over the dam-construction activities in the area threatening the flow of water to countries like Cambodia and Vietnam that rely on it.[38] With precipitation patterns expected to become more inconsistent as climate change progresses, countries facing the threat of water scarcity may be forced to explore larger global freshwater repositories, including Greenland and Antarctica.

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[32] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 8.

[33] Some global fishery models project a global annual marine fishery catch decrease of roughly 1.5 million tons at 1.5°C global warming, compared to a decrease of more than three million tons at 2°C global warming. See Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018), p. 9.

[34] "Irrigation Water Use," *United States Geological Survey,* June 7, 2018, https://www.usgs.gov/special-topics/water-science-school/science/irrigation-water-use #:~:text=thousands%20of%20years.

[35] Vincent Gitz, Alexandre Meybeck, L. Lipper, C. De Young, and S. Braatz, "Climate Change and Food Security: Risks and Responses," *Food and Agriculture Organization of the United Nations (FAO) Report* 110 (2016), p. x.

[36] "Climate Change Indicators: Drought," *United States Environmental Protection Agency*, July 17, 2021, https://www.epa.gov/climate-indicators/climate-change-indicators-drought; Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018), p. 177.

[37] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 2, 10.

[38] "Ibid, p. 10.

Energy Security

Water and energy security overlap when it comes to hydropower, which is a key source of emissions-free power generation via dams. The increased risk of droughts associated with climate change raises concerns for hydroelectric energy generation. Today, hydropower accounts for over 30 percent of the world's capacity of renewable energy sources.[39] As climate change alters precipitation patterns and increases the likelihood of drought conditions, however, hydropower may be at increasing risk in affected areas. Hydroelectric power plants require reliable flowing water sources to generate electricity. As the risk for extreme drought conditions grows with mean global temperature rises, hydropower plants' reservoir levels may drop below the height of intake levels needed for the hydroelectric turbines to function.[40] Thus, in a severe drought hydroelectric power may become unavailable due to too low water levels, a concern that becomes compounded during prolonged heat waves when electricity demands are high. If water levels drop too low at hydroelectric power plants, facilities will be forced to switch to other means of electricity generation, with most likely making up the difference by burning fossil fuels.[41] This has already been demonstrated in the United States when California experienced such severe and extended drought conditions in 2021 that it had to shut down a hydropower plant and increase its reliance on natural gas to prevent electrical blackouts.[42]

The increased probability of droughts due to climate change calls into question the reliability of hydroelectric power as a renewable energy source in various regions. Although hydropower is one of the largest sources of renewable energy today, it would still need to double in capacity by 2050 to help limit global warming to below 2°C.[43] The availability of hydropower is also critical when complementing other renewable energy sources. Even if mean water levels in reservoirs remained *generally* unchanged, variability of future precipitation patterns could cause those levels to fluctuate significantly at times, which may affect hydropower plants' ability to act as *reliable* backup systems for intermittent weather-dependent energy sources like wind and solar during unusually dry periods.[44] This in consequence could force countries now relying heavily on hydropower for renewable power generation back to fossil fuels to meet energy demands.

Changes in the Geophysical Environment

Climate change is likely to cause significant macro-changes in the geophysical environment. These macro-changes could occur in the oceans and in higher altitude parts of the atmosphere.

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[39] "Facts about Hydropower," *International Hydropower Association,* https://www.hydropower.org/iha/discover-facts-about-hydropower.

[40] Brian Tarroja, "Hydroelectric Drought: How Climate Change Complicates California's Plans for a Carbon-Free Future," *Bulletin of the Atomic Scientists*, August 16, 2021, https://thebulletin.org/2021/08/hydroelectric-droughtfgray-how-climate-change-complicates-californias-plans-for-a-carbon-free-future/.

[41] Alex Fox, "Western Drought Drives Decline in Hydroelectric Power Generation," *Smithsonian Magazine*, October 13, 2021, https://www.smithsonianmag.com/smart-news/western-drought-drives-decline-in-hydroelectric-power-generation-180978862/.

[42] Brian Tarroja, "Hydroelectric Drought: How Climate Change Complicates California's Plans for a Carbon-Free Future," *Bulletin of the Atomic Scientists*, August 16, 2021, https://thebulletin.org/2021/08/hydroelectric-droughtfgray-how-climate-change-complicates-californias-plans-for-a-carbon-free-future/.

[43] "Facts about Hydropower," *International Hydropower Association,* https://www.hydropower.org/iha/discover-facts-about-hydropower.

[44] Brian Tarroja, "Hydroelectric Drought: How Climate Change Complicates California's Plans for a Carbon-Free Future," *Bulletin of the Atomic Scientists*, August 16, 2021, https://thebulletin.org/2021/08/hydroelectric-droughtfgray-how-climate-change-complicates-californias-plans-for-a-carbon-free-future/.

The most dramatic consequence of climate change is rising sea levels, which will be discussed below. Less dramatic, but potentially more consequential, climate change may have the potential to alter ocean currents, which in turn may significantly affect weather patterns and temperatures in various areas of the world. Covering 70 percent of the global surface, oceans have helped influence the climate by absorbing solar radiation and releasing heat, driving atmospheric circulation.[45] Yet, as greenhouse gases trap more energy from the sun, the oceans are absorbing more heat, resulting in rising sea temperatures and changing current circulations.[46] Major Arctic ice melt could potentially also trigger major current flow changes in the North Atlantic Ocean such that Europe and North America could suffer a "mini-Ice Age," with temperatures dropping as much as 5-9 degrees Celsius within a few decades for a prolonged period according to some studies.[47] Similar effects in terms of new cold and/or hot temperature extremes in other regions of the world if major "conveyor belt" currents such as the Kuroshio Current were to be slowed or otherwise significantly altered as a consequence of global warming.

The oceans are a major "carbon sink," that is, absorb as much as 30% of human-generated carbon emissions.[48] Some estimates note that were the ocean not able to absorb so much CO2, atmospheric CO2 levels would far greater than they currently are.[49] Consequences include increasing acidification of the oceans that could alter marine food chains, affect human food supply, reduce storm protection of coastal areas by reefs, and negatively impact industries such as tourism.[50]

While the *Net Zero 2050* report uses warming global surface temperatures for its reference standard, the temperatures in other, higher-altitude parts of the atmosphere will also be warmer. As a result of the growing CO2 and other greenhouse gas emissions concentration, the upper atmosphere is becoming warmer and hence less dense. This has practical ramifications for the space domain in that the atmosphere serves the very valuable role of helping to incinerate through atmospheric friction large amounts of "space junk," e.g., dead satellites in decaying low earth orbits, debris from orbital collisions, fragments of machinery discarded in space, and items that have detached from rockets.[51] But as carbon dioxide and greenhouse gas emissions increase, the density of the upper atmosphere is

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[45] Dana Bolles, "Climate Variability," *NASA Science*, last updated May 21, 2022, https://science.nasa.gov/earth-science/oceanography/ocean-earth-system/climate-variability.

[46] "Climate Change Indicators: Oceans," *Environmental Protection Agency*, last updated May 12, 2021, https://www.epa.gov/climate-indicators/oceans. See also Paul Voosen, "Global warming is speeding up ocean currents. Here's why," April 20, 2022, https://www.science.org/content/article/global-warming-speeding-ocean-currents-here-s-why; and U.S. National Ocean and Atmospheric Administration, "How does the ocean affect climate and weather on land?", https://oceanexplorer.noaa.gov/facts/climate.html.

[47] NASA, "A Chilling Possibility," March 5, 2004, https://science.nasa.gov/science-news/science-at-nasa/2004/05mar_arctic. See also Bob Berwyn, "Climate Change is Weakening the Ocean Currents That Shape Weather on Both Sides of the Atlantic," February 25, 2021, *Inside Climate News*, https://insideclimatenews.org/news/25022021/climate-change-ocean-currents-atlantic/; and James Temple, "The Atlantic's vital currents could collapse. Scientists are racing to understand the dangers.", December 14, 2021, https://www.technologyreview.com/2021/12/14/1041321/climate-change-ocean-atlantic-circulation/.

[48] Katie Lebling and Eliza Northrop, "Leveraging the Ocean's Carbon Removal Potential," October 8, 2020, *World Research Institute*, https://www.wri.org/insights/leveraging-oceans-carbon-removal-potential; "UNESCO cautions ocean risks losing its ability to absorb carbon, exacerbating global warming," April 27, 2021, *United Nations Educations, Scientific, and Cultural Organization (UNESCO)*, https://en.unesco.org/news/unesco-cautions-ocean-risks-losing-its-ability-absorb-carbon-exacerbating-global-warming.

[49] Jamie Shutler and Andy Watson (University of Exeter), "The oceans are absorbing more carbon than previously thought," September 28, 2020, CarbonBrief (CB), https://www.carbonbrief.org/guest-post-the-oceans-are-absorbing-more-carbon-than-previously-thought/.

[50] "Understanding Ocean Acidification," U.S. National Oceanic and Atmospheric Administration (NOAA), https://www.fisheries.noaa.gov/insight/understanding-ocean-acidification.

[51] Jonathan O'Callaghan, "What if Space Junk and Climate Change Become the Same Problem?" *The New York Times,* May 12, 2021, https://www.nytimes.com/2021/05/12/science/space-junk-climate-change.html.

decreasing steadily, which may diminish this effect and leave more orbital debris in space.[52] With global warming leading to the atmosphere losing density, the ability for it to draw objects into a natural decay and be incinerated is lessened, potentially allowing more debris to impact the Earth's surface.[53] Since 2000, the Earth's atmosphere at 250 miles altitude has become 21 percent less dense due to increasing carbon dioxide levels.[54] In the worst-case global warming scenarios, this percentage could rise to as much as 80 percent by 2100, meaning less debris gets drawn into the lower atmosphere to be destroyed, and more of the debris that does enter the atmosphere survives to strike Earth's surface.[55] The practical impact of this is that a growing amount of space debris will significantly increase the hazards to new satellites being launched into orbit, even as the number of commercial satellites being launched is growing at a rapid rate. Currently there are over 4,500 operational satellites in orbit around the Earth at any one time, a figure projected to rise dramatically in coming years, especially in low-Earth orbits (LEO).[56]

Impacts of Rising Sea Levels

As mean global temperatures increase, the world's glaciers and ice sheets will continue to melt, subsequently raising global mean sea levels (GMSL). Although past and future sea level rise varies by region, it is already negatively impacting small islands and low-lying coastal regions in many locations worldwide.[57] The Arctic, particularly, is now experiencing significant global warming at a rate of two to three times the annual global average.[58] The Antarctic ice sheet is the single largest potential source of global sea level rise, though uncertainty concerning the rate of future melting means that the amount of sea level rise that may occur as a consequence must also remain uncertain.[59] Today, the disappearance of large areas of both Arctic and Antarctic sea ice may result in the opening of new sea routes and areas of commerce and the discovery and exploitation of natural resource reserves previously not accessible under the ice. As both polar and non-polar states increase their attention towards the respective poles, the increased presence of nations with competing interests may usher in a new frontier for strategic competition.

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[52] Jonathan O'Callaghan, "What if Space Junk and Climate Change Become the Same Problem?" *The New York Times,* May 12, 2021, https://www.nytimes.com/2021/05/12/science/space-junk-climate-change.html.

[53] Ibid.

[54] M.K. Brown, H.G. Lewis, A.J. Kavanagh, and I. Cnossen, "Future Decreases in Thermospheric Neutral Density in Low Earth Orbit Due to Carbon Dioxide Emissions," *Journal of Geophysical Research: Atmospheres* 126, no. 8, April 2021.

[55] Jonathan O'Callaghan, "What if Space Junk and Climate Change Become the Same Problem?" *The New York Times,* May 12, 2021, https://www.nytimes.com/2021/05/12/science/space-junk-climate-change.html.

[56] "UCS Satellite Database," *Union of Concerned Scientists*, December 8, 2005 (last updated January 1, 2022), https://www.ucsusa.org/resources/satellite-database.

[57] M. Oppenheimer, B.C. Glavovic, J. Hinkel, R. van de Wal, A.K. Magnan et al, "Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities," in: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)], (Cambridge University Press, Cambridge, UK and New York, NY, USA, 2019), p. 324.

[58] Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018), p. 4.

[59] M. Oppenheimer, B. Glavovic, J. Hinkel, R. van de Wal, A. K. Magnan, A. Abd-Elgawad et al, "Sea Level Rise and Implications for Low Lying Islands, Coasts, and Communities," in *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, eds. H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (Cambridge, UK: Cambridge University Press, 2019), 321-445.

Low-Lying Coastal Areas and Small Islands

These geographic features are by definition the most vulnerable to sea level rise. For many if not most littoral countries, substantial populations and physical infrastructure are located close to the coast and are highly vulnerable to the effects of significantly higher sea levels. This is especially the case for nations with large expanses of low-lying coastal areas, such as Bangladesh or the Netherlands. For some small island nations, such as the Maldives and the Marshall Islands, it is an existential threat absent effective adaptation.

Since 1880, the GMSL has risen between 8 to 9 inches, with roughly one-third of the rise coming during the last two and a half decades.[60] As global temperatures continue to increase, the rate of sea level rise will only accelerate. Low-lying coastal areas and small islands at nearly all latitudes are at risk.[61] These will face the greatest natural threats from the physical effects of climate change-driven sea level rise, including erosion of coastlines, inundation of river deltas, destruction of marshes and wetlands, loss of wildlife and biodiversity, and eventually migration of human populations.[62]

Besides the natural threats, much critical infrastructure, including ports, airports, major roadways, power plants, and military bases, is located on or near the coast in low-lying areas. In a 2018 study roughly 20 percent of small island nations' landmass will face annual flooding from higher sea levels, with the potential to severely damage infrastructure located on the shores.[63] Not only will these assets be at risk from rising sea levels, but there is increased likelihood of extreme weather events causing severe flooding and storm surges that can damage that critical infrastructure, including military bases and facilities and the assets that they host. For many small island nations, unfortunately the cost to combat rising sea levels will be unaffordable, making it more difficult for them to ameliorate the physical impacts of climate change.[64] This is due to the large overhead cost of infrastructure projects such as dikes and seawalls, with the per capita unit cost for small island nations being substantially higher than for similar projects on larger landmasses.

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[60] Even if countries can meet the 2015 Paris Agreement targets, the global mean sea level is predicted to rise between 0.26 and 0.77 meters by 2100. See Rebecca Lindsey, "Climate Change," National Oceanic and Atmospheric Administration, August 14, 2020, https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level and Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018), p. 7.

[61] M. Oppenheimer, B.C. Glavovic, J. Hinkel, R. van de Wal, A.K. Magnan et al, "Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities," in: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)], (Cambridge University Press, Cambridge, UK and New York, NY, USA, 2019), p. 324.

[62] C. Mbow, C. Rosenzweig, L.G. Barioni, T.G. Benton, M. Herrero et al., "Food Security," in *Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, ed. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Portner et al, (2019), p. 517.

[63] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 14.

[64] L.A. Nurse, R.F. McLean, J. Agard, L.P. Briguglio, V. Duvat-Magnan et al., "Small Islands," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [V.R. Barros, C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach et al, (eds.)], (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2014), p. 1626.

The negative impacts of climate change will only be exacerbated in cases of land reclamation.[65] Reclaiming land from the sea is not a new activity and has been occurring for centuries across the world. Some of the most prominent examples of land reclamation projects include most of India's Mumbai coastline, Dubai's Palm Islands, the Marina Bay in Singapore, and artificial islands.[66] Yet, many of these artificially created new land masses are at even greater risk than small islands and low-lying coastal areas, and face the prospects of enhanced erosion and flooding.

Significant sea level rises will pose particular dangers to naval and coast guard bases and facilities, most of which are sited in coastal areas for obvious reasons.[67] This will result in higher budgetary expenditures for protective measures such as dikes or higher seawalls, repair and remediation of damage, and civil engineering support requirements. If future sea level rise moves towards the higher end of projected possible sea levels, many coastal nations with significant sea services may become faced with the choice between either making large ongoing investments in protective measures or else displacing and moving bases and facilities to alternative new locations. Both options involve very large military construction expenditures.

One other issue of potentially serious military concern arises in Oceania, where several small low-lying island nations, e.g., the Marshall Islands and Palau, host military bases or facilities used by the United States and allies. Several of these face potentially existential threats from sea level rise. In some cases, while the threat may not be existential, sea level rise may render bases and facilities unusable. Efforts to mitigate the impacts of that rise are not affordable by those small nations, hence will require outside financial support if those bases or facilities are to remain available.

Impacts of Rising Temperatures in the Polar Regions

The polar regions provide perhaps the most dramatic example of the nexus between national security and climate change. As climate change impacts these regions, there will be new issues involving national defense, commerce, and resource development and exploitation. The Arctic region in particular may see substantial increases in military and commercial interests and presence, and the involvement of new parties that have not previously demonstrated significant interest in that area. The Antarctic and the seas around it will also see new actors and interests, though not of the same type or scale as the Arctic.

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[65] M. Oppenheimer, B.C. Glavovic, J. Hinkel, R. van de Wal, A.K. Magnan et al, "Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities," in: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)], (Cambridge University Press, Cambridge, UK and New York, NY, USA, 2019), p. 324.

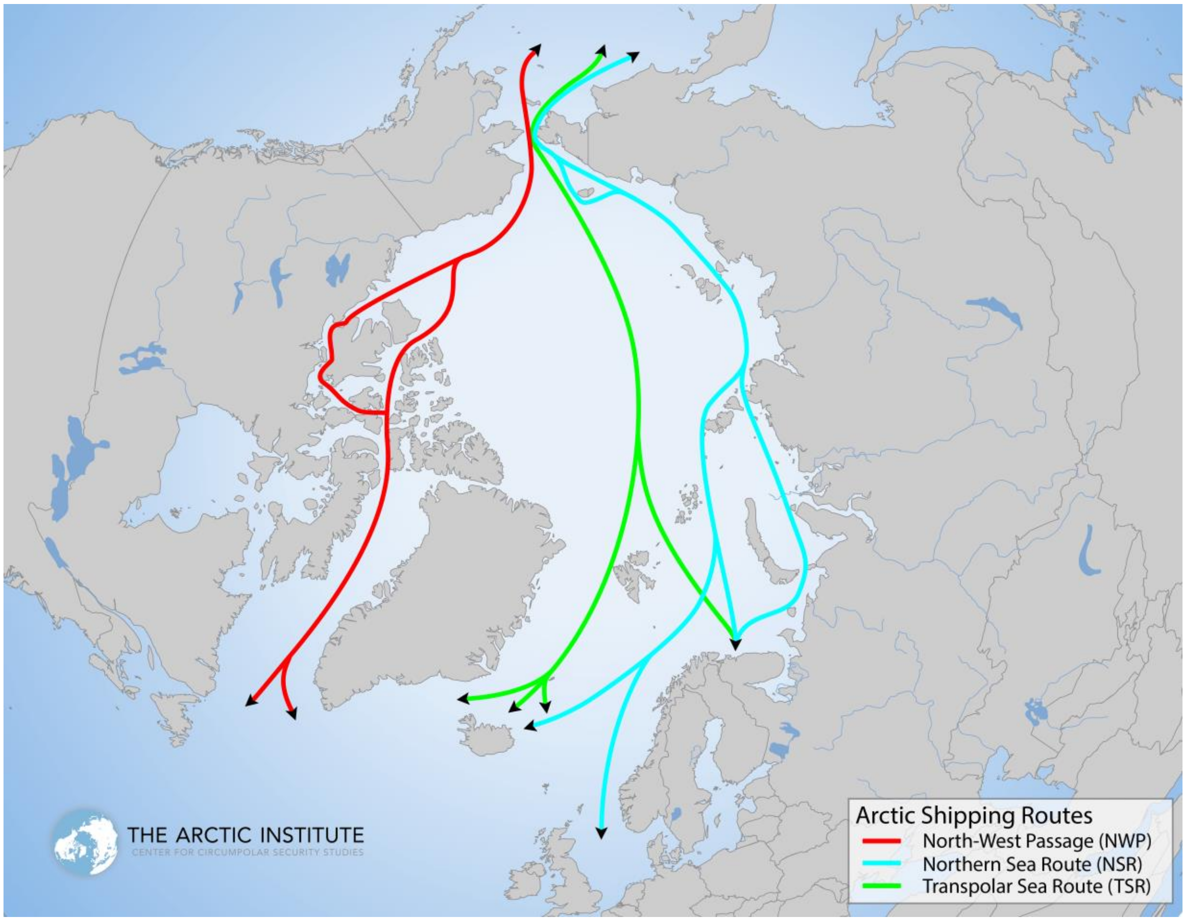
[66] Modus Staff, "Out of the Deep: 7 Massive Land Reclamation Projects," *RICS,* June 14, 2021, https://ww3.rics.org/uk/en/modus/natural-environment/land/out-of-the-deep--7-massive-land-reclamation-projects--.html.

[67] As an illustrative example, the city of Norfolk, Virginia, home to the largest naval base in the world, is already facing significant increases in flooding, which given current trends in sea level rise, may pose severe threats to the future viability of that base. See Robert Farley, "Climate Change Threatens the U.S. Navy's Main Base in Norfolk, Virginia," March 1, 2021, https://nationalinterest.org/blog/reboot/climate-change-threatens-us-navy%E2%80%99s-main-base-norfolk-virginia-178817.

The Arctic

As shown in Figure 1, at 1.5°C of global warming, the IPCC projects that an ice-free Arctic summer will occur once per century, versus at least once per decade at 2°C, an order of magnitude increase.[68] This will make viable for extended periods shipping lanes such as the "Northern Sea Route" (NSR) that run primarily along the Russian Arctic coast from Murmansk on the Barents Sea to the Bering Strait; the "North-West Passage" (NWP) running through the Canadian archipelago and north of Alaska; and the future "Transpolar Sea Route" (TSR), sometimes called the "Central Arctic Route" (CAR). (See Figure 2.)

FIGURE 2: ARCTIC POLAR SHIPPING ROUTES



Source: The Arctic Institute Center for Circumpolar Security Studies, https://www.thearcticinstitute.org/future-northern-sea-route-golden-waterway-niche/

The NSR can reduce shipping times, and thus costs, between Asia and Europe by nearly 40 percent during periods of no- or very thin ice, which would considerably benefit Asian countries such as Japan

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[68] Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018), p. 8.

as well as their European trading partners.[69] The NSR and NWP were of limited interest to shipping companies when thick "multiyear ice" blocked the coastal waters of both for all but icebreakers or specially hardened ships for almost all of the year. However, 2007 saw ice-free waters briefly in late summer of that year. Since then, global warming has progressively increased the periods and extent of ice-free waters along those routes. Importantly, the warming has also caused a permanent loss of thick multiyear ice in growing areas of the Arctic. While the threat of thin first-year "drift ice" has meant that ship speeds have been relatively slow compared with those used in traditional sea lanes, the rising Arctic temperatures have also steadily reduced the threat of drift ice, thereby increasing safe transit speeds and permitting use of the NSR by a wider range of ships during ice-free periods.[70]

FIGURE 3: POTENTIAL FUTURE ARCTIC POLAR SHIPPING ROUTES

Source: Arctic Portal, "Central Arctic Route in Use by 2050," https://arcticportal.org/ap-library/news/965-central-arctic-route-in-use-by-2050.[71]

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[69] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 8.

[70] Malte Humbert, "The Future of the Northern Sea Route – A "Golden Waterway" or a Niche Trade Route," *The Arctic Institute*, September 15, 2011, https://www.thearcticinstitute.org/future-northern-sea-route-golden-waterway-niche/.

[71] "OW" refers to "open water" ships, while "PC6" refers to ice-hardened vessels. If/when the Arctic Ocean were to be ice-free for much of the year, any non-hardened ship could use the Central Arctic Route.

Shipping companies currently report that use of the NSR running through coastal waters north of Russia can save them hundreds of thousands of dollars per voyage given their sharply reduced voyage lengths. In the future as the Arctic sea areas without ice for extended periods shrink as a consequence of warming and the resultant loss of thick multiyear ice in growing Arctic areas, the NSR will likely steadily widen, further shortening voyage lengths and thus costs. (See Figure 3.) Ultimately, if the Arctic Ocean were completely ice-free for such periods, making any polar route usable by all shipping, not just ice-hardened ones, the shipping cost savings realized could grow as much as an additional 40%.[72]

Given *Net Zero 2050*'s projection of an ice-free Arctic Ocean by 2050, if not significantly sooner, the economics of shipping will surely mean major increases in the volume of ship traffic between Asia and Europe via the NSR and the TSR/CAR. There will be ships sailing under many different flags, and thus more states with an economic interest and presence in the Arctic. Indeed, many non-Arctic states have already publicly declared their interests in the Arctic region, including India and China, which now have accredited observer status at the Arctic Council, a high level intergovernmental organization that cooperatively deals with issues in the Arctic region.[73]

Shipping is not the only economic interest given the future accessibility of greater areas of the Arctic Ocean, both in the ocean itself and on/beneath the seabed. The potential movement of fisheries into the Arctic due to ocean warming was noted earlier. The Arctic region also has very significant undersea natural resources (including oil, natural gas, and mineral fuels) that will become available for extraction and exploitation. According to some scientists, as much as 30 percent of the world's undiscovered natural gas and 13 percent of its undiscovered oil may be in the Arctic, most of it offshore.[74] The United States Geological Survey (USGS) estimates that the Arctic holds nearly 1.7 trillion cubic feet of natural gas and other mineral fuels, equal to the entirety of Russia's current oil reserve.[75] The precious metals and mineral deposits, alone, are estimated to be worth $1 trillion.[76]

Japan recognizes the latent possibilities through and under the Arctic Sea.[77] More than 30 years ago, it became the first non-Arctic state to establish an observation station in the Arctic, and in 2013 gained observer status on the Arctic Council as a non-Arctic state.[78] In 2015, Japan officially adopted an *Arctic*

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[72] "Central Arctic route in use by 2050," *Arctic Portal*, March 5, 2013, https://arcticportal.org/ap-library/news/965-central-arctic-route-in-use-by-2050.

[73] The Arctic Council membership is comprised of Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the U.S. See Jacob Koshy, "India hopes for permanent presence in Arctic," *The Hindu*, March 23, 2022, https://www.thehindu.com/news/national/india-hopes-for-permanent-presence-in-arctic/article65242915.ece; and Reuters Staff, "China pledges to build 'Polar Silk Road' over 2021-2025," *Reuters*, March 4, 2021, https://www.reuters.com/article/us-china-parliament-polar/china-pledges-to-build-polar-silk-road-over-2021-2025

[74] Donald L. Gautier et al, "Assessment of Undiscovered Oil and Gas in the Arctic," *Science* 324, no. 5931, May 2009.

[75] "Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle," *United States Geological Survey*, 2008, https://pubs.usgs.gov/fs/2008/3049/fs2008-3049.pdf; and "Russia," *U.S. Energy Information Administration*, 2021, https://www.eia.gov/international/analysis/country/RUS.

[76] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 8.

[77] "Japan's Arctic Policy," *The Headquarters for Ocean Policy*, October 16, 2015, https://www8.cao.go.jp/ocean/english/arctic/pdf/japans_ap_e.pdf.

[78] "Japan," *Arctic Council*, 2022, https://www.arctic-council.org/about/observers/non-arctic-states/japan/.

Policy, stating Japan's aims to promote international cooperation in the region, be mindful of the environment and ecosystem, and seek economic opportunities for the Arctic Sea Route.[79] In April 2021, the Japanese Minister of Defense stated that "from Japan to Europe, if we take a sea route via the Arctic Ocean, the distance can be reduced to 60% of the existing route via the Suez Canal."[80] By being the closest geographically located country in the Asian region to the Arctic Ocean, Japan is in a key strategic position.

China's interest in the Arctic has also increased over the last decade. In 2011, China included the polar regions in its 12th five-year plan for the first time and joined the Arctic Council as a non-Arctic state in 2013.[81] China's most robust stance on its position in the Arctic came in 2018 with the release of its official *Arctic Policy*, declaring China a "near-Arctic" state.[82] The document also outlined a "Polar Silk Road" (PSR) economic plan, prioritizing Chinese use of Arctic shipping routes and incorporating them into China's Belt and Road Initiative. With a current focus on developing commercial access to the Arctic, China hopes to invest in infrastructure along these opened shipping lanes.[83] Chinese officials have emphasized that China does not plan to interfere in the affairs between Arctic states, but that it also will not be absent, specifically highlighting scientific research and economic interests in the region.[84] Currently, China has continued to heavily invest in Arctic economic activities, including billions towards extracting energy resources from beneath the Yamal Peninsula in northern Russia.[85]

China's aspirations in the Arctic are often perceived alongside Russia's own activities in the region. Of the entire Arctic Ocean coastline, Russia stretches over 53 percent of it.[86] Its interest in the Arctic had deep historic roots, beginning with Russia's conquest of Siberia in the 16th century.[87] Today, it is one of the primary members of the Arctic Council, holding the first chairmanship from 2004 to 2006.[88] In 2020, Russia released its *Basic Principles of Russian Federation State Policy in the Arctic to 2035*,

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[79] "Japan's Arctic Policy," *The Headquarters for Ocean Policy*, October 16, 2015, https://www8.cao.go.jp/ocean/english/arctic/pdf/japans_ap_e.pdf, p. 2.

[80] Nobuo Kishi, Minister of Defense, "Climate Security Session: Leaders Summit on Climate," *Ministry of Defense*, April 23, 2021, https://www.mod.go.jp/en/article/2021/04/a88c937c30be56316213265a47eaccf669dc8ff4.html.

[81] China's five-year plan acts as a guide for the country's economic policies over the next five-years. See Marc Lanteigne, "The Polar Policies in China's New Five-Year Plan," *The Diplomat*, March 12, 2021, https://thediplomat.com/2021/03/the-polar-policies-in-chinas-new-five-year-plan/.

[82] Heljar Havnes and Johan Martin Seland, "The Increasing Security Focus in China's Arctic Policy," *The Arctic Institute*, July 16, 2019, https://www.thearcticinstitute.org/increasing-security-focus-china-arctic-policy/; "People's Republic of China," *Arctic Council*, 2022, https://www.arctic-council.org/about/observers/non-arctic-states/peoples-republic-of-china/; and "China's Arctic Policy," *State Council Information Office of the People's Republic of China*, January 26, 2018, http://english.www.gov.cn/; and Lu Hui, "China's Arctic Policy," *Xinhua*, January 26, 2018, http://www.xinhuanet.com/.

[83] "China's Arctic Policy," *State Council Information Office of the People's Republic of China*, January 26, 2018, http://english.www.gov.cn/; and Lu Hui, "China's Arctic Policy," *Xinhua*, January 26, 2018, http://www.xinhuanet.com/.

[84] Kong Soon Lim, "China's Arctic Policy & the Polar Silk Road Vision," *Arctic Yearbook 2018*, p. 3.

[85] Marisa R. Lino, "Understanding China's Arctic Activities," *The International Institute for Strategic Studies*, February 25, 2020, https://www.iiss.org/blogs/analysis/2020/02/china-arctic.

[86] "The Russian Federation," The Arctic Council, 2022, https://www.arctic-council.org/about/states/russian-federation/.

[87] "The Russian Discovery of Siberia," *The Library of Congress*, 2000, https://www.loc.gov/collections/meeting-of-frontiers/articles-and-essays/exploration/russian-discovery-of-siberia/.

[88] "The Russian Federation," The Arctic Council, 2022, https://www.arctic-council.org/about/states/russian-federation/.

outlining and defining its Arctic interests, goals, and means of implementation over the next 13 years.[89] Unlike China's economic emphasis, Russia has spent recent years investing resources into further developing its Arctic footprint in a range of areas, including building more icebreakers, opening oil and gas pipelines, and strengthening its military presence in the north.[90] As the world's third-largest producer of hydrocarbon resources, the Arctic presents a primary source for Russia's future economic growth, possessing major reserves of oil, natural gas, and coal.[91] Also high on Russia's economic list of priorities is the NSR, including interest in turning the opening Arctic sea routes into the equivalent of a maritime toll road, requiring payments to be made for pilots and icebreaker escorts.[92] However, it is not clear that Russia can lawfully do this under the provision of Article 58 of the United Nations Convention on the Law of the Sea.[93] Russia hopes to reach a level of traffic in the NSR of 80 million tons of shipping annually by 2024 and 110 million tons by 2030.[94]

The Antarctic

Net Zero 2050 also projects significant climate change-induced changes in the southern polar region. The Antarctic ice sheet is the largest potential source of, and most uncertain contributor to, future global mean sea level rise.[95] Unlike the Arctic, Antarctica has treaties in place to help govern the region and regulate relations among states to prohibit mineral resource exploitation, including the Antarctic Treaty adopted in 1959. This confirmed that Antarctica should be used for peaceful purposes only, including scientific observation.[96] In 1991, the Madrid Protocol also banned extractive mining and designated Antarctica as a "natural reserve, devoted to peace and science."[97] If signatory countries wish to modify the Protocol they must wait until 2048, and then it can only be modified by unanimous agreement. Despite the stringent guidelines currently governing Antarctica, however, some nations have expressed interest in altering these treaties to allow the pursuit of economic activity.[98]

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[89] Ekaterina Klimenko, "Russia's New Arctic Policy Document Signals Continuity Rather than Change," *Stockholm International Peace Research Institute (SIPRI),* April 6, 2020, https://www.sipri.org/commentary/essay/2020/russias-new-arctic-policy-document-signals-continuity-rather-change.

[90] Jonathan Jordan, "Russia's Coercive Diplomacy in the Arctic," *The Arctic Institute*, July 6, 2021, https://www.thearcticinstitute.org/russia-coercive-diplomacy-arctic/.

[91] Donald L. Gautier et al, "Assessment of Undiscovered Oil and Gas in the Arctic," *Science* 324, no. 5931, May 2009; "The Russian Federation," The Arctic Council, 2022, https://www.arctic-council.org/about/states/russian-federation/.

[92] Andrew E. Kramer, "In the Russian Arctic, the First Stirrings of a Very Cold War," *The New York Times*, May 22, 2021, https://www.nytimes.com/2021/05/22/world/russia-us-arctic-military.html.

[93] See https://www.un.org/depts/los/convention_agreements/texts/unclos/part5.htm.

[94] "Russia's Northern Sea Route Posts Record Year for Traffic Volume," *The Maritime Executive*, December 23, 2021, https://www.maritime-executive.com/article/russia-s-northern-sea-route-posts-record-year-for-traffic-volume.

[95] M. Oppenheimer, B. Glavovic, J. Hinkel, R. van de Wal, A. K. Magnan, A. Abd-Elgawad et al, "Sea Level Rise and Implications for Low Lying Islands, Coasts, and Communities," in *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, eds. H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (Cambridge, UK: Cambridge University Press, 2019), 321-445.

[96] "The Antarctic Treaty," *Secretariat of the Antarctic Treaty*, 2022, https://www.ats.aq/e/antarctictreaty.html.

[97] Specifically, Article 7 of the protocol prohibits all activities relating to Antarctic mineral resources except for scientific research. The ban on any mineral resource activities in the region cannot be removed from the Protocol unless a binding legal regime on mineral resource activities in Antarctica is in effect. See "The Protocol on Environmental Protection to the Antarctic Treaty," *Secretariat of the Antarctic Treaty*, 2022, https://www.ats.aq/e/protocol.html.

[98] Nengye Liu, "What Are China's Intentions in Antarctica?" *The Diplomat*, June 14, 2019, https://thediplomat.com/2019/06/what-are-chinas-intentions-in-antarctica/#:~:text=So%20far%2C%20China%20has%20four,polar%20voyage%20in%20late%202019.

The Southern Ocean encircling Antarctica provides an ideal opportunity for further developing certain industries, including krill fisheries. The Antarctic krill population offers one of the last untouched marine resources on Earth, but over the last 60 years, surface krill populations have declined by as much as 50 percent, largely due to global warming and melting sea ice.[99] Currently, krill catch limits are managed under the Convention for the Conservation of Antarctic Marine Living Resources.[100] As the Antarctic sea ice sheet continues to melt, new fishery prospects may open in the future. China, in conjunction with Russia, has used international forums to block the establishment of new marine protected areas surrounding Antarctica, with a potential interest in the latent fishing possibilities in the Southern Ocean.[101]

Geopolitical Competition and Militarization of the Polar Regions

In a race to conquer the world's "final frontier," the Arctic is becoming crowded with the presence of both Arctic and non-Arctic nations who may have conflicting interests. As the accessibility of exploitable ocean areas increases as a consequence of global warming, more countries have sought to stake claims within the Arctic region. The presence of competing nations is expected to increase as states seek to exploit maritime routes and extract mineral and energy deposits, particularly as their economic value grows.

Although competition in the Arctic is likely to remain in the economic sphere, as commercial and military activity grows in the area, the risk of miscalculation will increase.[102] For countries with long historical ties to the Arctic, the increased presence of non-Arctic states may amplify existing concerns, with some nations perceiving it as a challenge to their regional sovereignty and territorial integrity.

As various nations' economic interests in the Arctic increase, some increase in military presence by some of them should be expected. And, to the extent that shipping flows through the Arctic increase very significantly, particularly during extended ice-free periods assumed by the *Net Zero 2050* report, those sea lines of communication (SLOC) could become increasingly vulnerable, and thus potentially require protection, preferably through international law but possibly by military force presence.

Signatories of the United Nations Convention on the Law of the Sea (UNCLOS) are entitled to resources that lie within their EEZ, which generally extend to 200 nautical miles beyond their territorial sea.[103] However, most of the natural gas resources in the Arctic are beyond these legal borders.[104] Russia accordingly has recently sought to expand its Arctic EEZ significantly by submitting

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[99] Martin Edwards, Pierre Hélaouët, Eric Goberville, Geraint A. Tarling, Michael T. Burrows et al, "North Atlantic Warming Over Six Decades Drives Decreases in Krill Abundance with No Associated Range Shift," *Communications Biology* 4, no. 644 (2021), p. 1.

[100] "Krill Fisheries," *Commission for the Conservation of Antarctic Marine Living Resources*, last updated July 2, 2021, https://www.ccamlr.org/en/fisheries/krill-fisheries.

[101] Alexander B. Gray, "China's Environmental Threat to Antarctica," *The Wall Street Journal*, December 1, 2021, https://www.wsj.com/articles/china-environmental-threat-to-antarctica-research-mining-satellites-telescopes-11638394184.

[102] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 8.

[103] See https://www.un.org/depts/los/convention_agreements/texts/unclos/part5.htm.

[104] Tullio Treves, "United Nations Convention on the Law of the Sea," *United Nations Audiovisual Library of International Law* (2008), http://untreaty.un.org/cod/avl/pdf/ha/uncls/uncls_e.pdf; and "Arctic Oil and Natural Gas Resources," *U.S. Energy Information Administration*, January 20, 2012, https://www.eia.gov/todayinenergy/detail.php?id=4650.

new claims, including some that overlap with Canadian and Danish claimed EEZs, to the United Nations.[105]

Of all the Arctic nations, Russia possesses the longest Arctic coastline, with approximately 1/5 of its territory found north of the Arctic Circle. This provides it a heavily vested interest in protecting its borders and interests as more countries turn their focus to the region.[106] As Russia continues to develop the Arctic for its potential economic prospects, it is also working to ensure its own security in the region.[107] For most of Russia's history, it has been protected in the north by the frozen Arctic Ocean. As the Arctic continues to melt, however, Russia must now consider a new theater of operation and new borders to be protected. Since 2018, Russia has repeatedly stated that non-Arctic countries do not have a military role in the region, while continuing its own military investments.[108] Over the last decade Russia has engaged in a substantial and sustained effort to strengthen its military presence in the Arctic, refurbishing Cold War-era bases, constructing new ones along the NSR, and expanding its fleet of nuclear-powered icebreakers.[109] In 2014, Russia created a Northern Joint Strategic Command to coordinate its military assets in the Arctic, including the Northern Fleet.[110] Nonetheless, Russia's current military posture remains defensive in nature, ensuring the defense of the Kola Peninsula and access to the NSR.[111]

As noted earlier, China's presence in the Arctic and Antarctic has also increased. It maintains scientific stations in both the Arctic and Antarctica, makes recurrent expeditions to both polar regions, and is expanding its fleet of icebreaker ships and building a salvage vessel designed for polar use.[112] To some in the international community there is concern over whether China's polar ambitions will remain solely in the economic sphere or also take on a military dimension.[113] The U.S. 2019 *Arctic Strategy* document goes as far as to state that both China and Russia are "pursuing activities and capabilities in

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[105] See "Russia Claims Continental Shelf in Arctic Ocean," *The Moscow Times*, April 12, 2021, https://www.themoscowtimes.com/2021/04/12/russia-claims-continental-shelf-in-arctic-ocean-a73566.

[106] Marisa R. Lino, "Understanding China's Arctic Activities," *The International Institute for Strategic Studies*, February 25, 2020, https://www.iiss.org/blogs/analysis/2020/02/china-arctic.

[107] Ekaterina Klimenko, "Russia's New Arctic Policy Document Signals Continuity Rather than Change," *Stockholm International Peace Research Institute (SIPRI),* April 6, 2020, https://www.sipri.org/commentary/essay/2020/russias-new-arctic-policy-document-signals-continuity-rather-change.

[108] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 8.

[109] Stephanie Pezard, Abbie Tingstad, Kristin Van Abel, and Scott Stephenson, *Maintaining Arctic Cooperation with Russia*, (Santa Monica, CA: RAND Corporation, 2017), p. 12.

[110] Previously, Russi's command structure in the Arctic was divided between three different commands. See Stephanie Pezard, Abbie Tingstad, Kristin Van Abel, and Scott Stephenson, *Maintaining Arctic Cooperation with Russia*, (Santa Monica, CA: RAND Corporation, 2017), p. 12.

[111] Mathieu Boulègue, "Russia's Military Posture in the Arctic: Managing Hard Power in a 'Low Tension' Environment," *Chatham House: The Royal Institute of International Affairs*, June 2019, p. 2.

[112] Ekaterina Uryupova, "What does China's new heavy icebreaker mean?", *Polar Journal*, November 27, 2021;, https://polarjournal.ch/en/2021/11/27/what-does-chinas-new-heavy-icebreaker-mean/; and Jeremy Greenwood, "The Polar Silk Road will be cleared by Chinese icebreakers," *The Brookings Institution*, November 24, 2021, https://www.brookings.edu/blog/order-from-chaos/2021/11/24/the-polar-silk-road-will-be-cleared-with-chinese-icebreakers/.

[113] Heljar Havnes and Johan Martin Seland, "The Increasing Security Focus in China's Arctic Policy," *The Arctic Institute*, July 16, 2019, https://www.thearcticinstitute.org/increasing-security-focus-china-arctic-policy/; Marisa R. Lino, "Understanding China's Arctic Activities," *The International Institute for Strategic Studies*, February 25, 2020, https://www.iiss.org/blogs/analysis/2020/02/china-arctic.

the Arctic that may present risks to the homeland."[114] Similarly, in the 2021 *Defense of Japan* white paper, the Ministry of Defense notes that while current Chinese focus is on commercial interests in the region, future moves made by the People's Liberation Army (PLA) Navy into the Arctic Ocean would attract Japan's attention.[115] To date, however, China's Arctic policies have focused exclusively on scientific aspirations and economic development. China has no permanent Arctic military presence, nor has it publicly expressed interest in pursuing this route.

While most of the Arctic region still remains generally inaccessible most of the year, rapidly disappearing ice will soon make future use of new shipping routes and extraction of key resources increasingly feasible and cost-effective. The Arctic's physical environment, including weather conditions, will remain harsh and unforgiving absent major climate change going even beyond the NIC's and IPCC's 2^{o}C rise scenario – and then only if that were to have benign effects in the Arctic region, which is unpredictable. The lack of supporting infrastructure in the polar regions is a further challenge that may limit activity beyond what has been described in this section.

Today, the Arctic remains an area of low tension. But as the world continues to warm and thereby alter the polar strategic landscape and the economic stakes there, so too may the race heat up to stake a claim in the world's "final frontier."

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[114] Office of the Under Secretary of Defense for Policy (OUSD-P), *Report to Congress: Department of Defense Arctic Strategy,* (Washington, D.C.: Department of Defense, June 2019), p. 6.

[115] Ministry of Defense of Japan, *Defense of Japan 2021* (Japan: Ministry of Defense of Japan, 2021), available at https://www.mod.go.jp/en/publ/w_paper/wp2021/DOJ2021_EN_Full.pdf, p. 192-193.

CHAPTER 3

Mitigating the Effects of Climate Change

The effects of climate change postulated in the *Net Zero 2050* report will require substantial mitigation and adaptation efforts. In terms of mitigation, the projected growing number and frequency of large-scale damaging natural events stemming from increased global warming, such as severe large-area storms such as supertyphoons or cyclones, and their consequences as they affect large populations must be addressed. Activities to do so will include humanitarian assistance and disaster relief (HA/DR) operations; peacekeeping operations; and, possibly, anti-terrorism and anti-piracy operations.

As the effects of climate change become increasingly felt in different regions of the world, governments must plan for ways to deal with the growing range of problems and dangers created by a warming planet. In the past, the main threats to a state's national security have traditionally been seen as coming from threats of attack posed by hostile powers, and more recently by terrorists and other non-state actors. Those threats thus needed to be dealt with primarily by a country's military and paramilitary forces and those of its allies. But as discussed earlier, the several non-military threats and dangers posed by climate change require that the notion of "security" be seen in a broader context. Many of these will nonetheless require the employment of military, paramilitary (e.g., Coast Guard), and other security forces to protect a country against, and mitigate the effects stemming from, climate change.

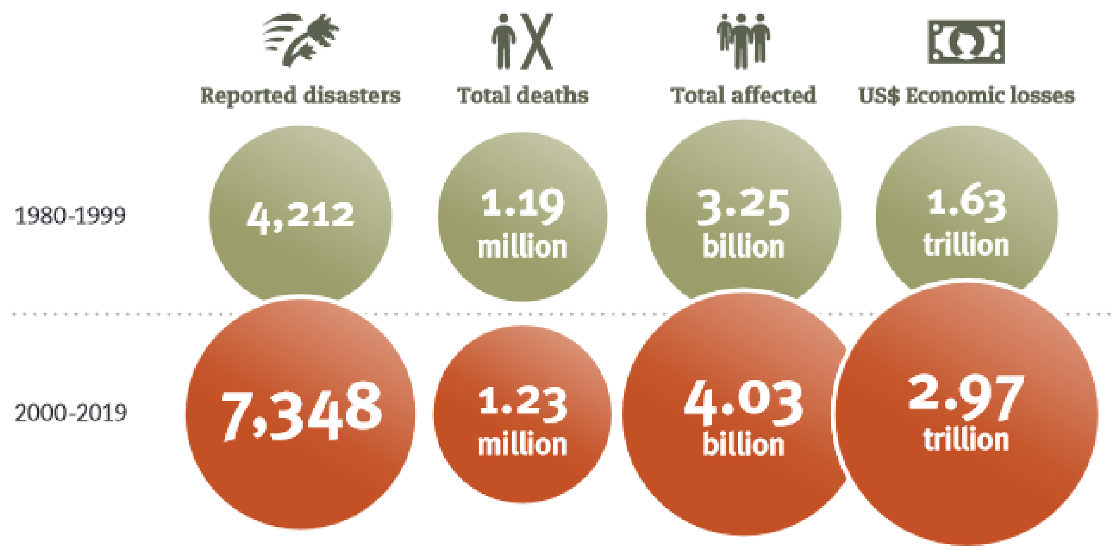
Then, many underdeveloped and/or poor countries lack the resources to ameliorate the impacts of climate change on their populations, property, and infrastructure. Fortunately, there are international organizations and mechanisms that exist to help such disadvantaged countries mitigate and/or recover from the effects of climate change-caused natural events such as severe storms, prolonged droughts, flooding, and so forth. International organizations, often through the United Nations, can intervene to assist in situations or scenarios involving large-scale human disasters, such as starvation due to conflict, mass migrations (whether due to conflict or natural disaster), or wars over scarce resources.

Much could also be done to help underdeveloped countries with pre-emptive investments to improve their infrastructure and to heighten their resilience in the event of extreme climate change-attributable events.

The Scale of the Problem

To provide an idea of the scale of the problems caused by climate change to date, the Centre for Research on the Epidemiology of Disaster recently issued a report, sponsored by the United Nations Office for Disaster Risk Reduction, comparing the human and economic losses incurred through natural hazard-related disasters suffered during 2000-2019 compared to the previous twenty year period. The report states that much of the substantial increase in disasters over the latter period can be attributed to climate change.[116] (See Figures 4 and 5.)

FIGURE 4: DISASTER IMPACTS 1980-1999 VS. 2000-2019



1 For the purposes of this report, the term "disaster" will only be reserved for natural hazard-related disasters, excluding biological and technological disasters.
2 All economic figures are adjusted to inflation for US$ 2019.
3 Climate-related disasters include disasters categorized as meteorological, climatological, or hydrological.

As illustrated in Figure 5, by far the largest number of natural hazard-related disasters have come from floods and storm, the severity of which this report as well as others such as *Net Zero 2050*, the NIC NIE, and the several IPCC quadrennial reports have attributed to climate change. Droughts and wildfires, while lesser in number, add to the increased climate change-attributed disaster totals.

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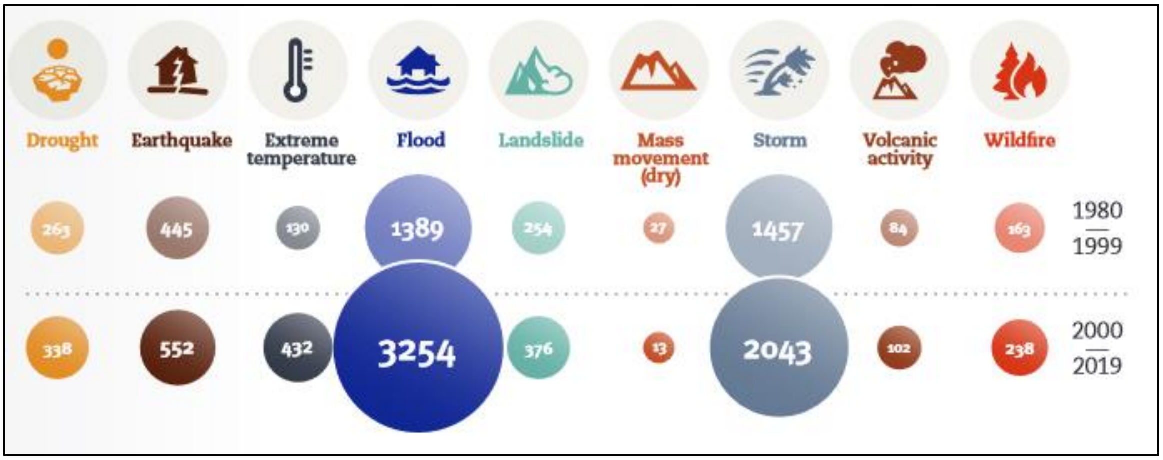
[116] Mami Mizutori and Debarati Guha-Sapir, *Human Cost of Disasters: An Overview of the Last Twenty Years 2000-2019*, UN Office for Disaster Risk Reduction / Centre for Research on the Epidemiology of Disaster, 2020, https://www.undrr.org/media/48008/download. See www.emdat.be/explanatory-notes for the criteria the Centre used to define "disaster."

FIGURE 5: TOTAL DISASTER TYPES: 1980-1999 VS. 2000-2019



Humanitarian Assistance/Disaster Relief (HA/DR)

Large-scale HA/DR operations are extraordinarily complex activities. Typical HA/DR operations can include delivering medical care, food and water; repairing electrical grids; conducting search-and-rescue; and evacuating people. Thus, they require a wide range of assets, both in terms of personnel, equipment, and supplies, and comprise various activities that require high degrees of coordination, and generally must be conducted under heavy time stress in order to save lives. The logistics, security, coordination or command & control (C^2), and in many cases civil engineering capabilities involved are as challenging as those required for military operations, and in fact bear considerable resemblance to them. In general, militaries, and to some extent paramilitary entities like coast guards, are the only organizations capable of conducting such complex operations on a large scale on compressed timelines to address major disasters.[117]

Thus, as the number, kinds, and scale of natural disasters attributable to the effects of climate change likely increase, potentially at a faster rate than over the past twenty years, more advanced countries with larger militaries will be more frequently called upon to employ them in HA/DR operations. Countries like the United States and Japan, which are liable to be struck by very powerful hurricanes or typhoons, already have extensive experience of using their militaries to assist civil authorities in dealing with disasters at home. For example, during 2005's Hurricane Katrina, which devastated large parts of the U.S. Gulf of Mexico coast, U.S. Navy (and Coast Guard) units were tasked to provide substantial medical, delivery of supplies, search-and-rescue, and even electrical power support to the worst affected areas. During Hurricane Sandy in 2012, the Department of Defense mobilized 14,000 military personnel, including an additional 10,000 providing assistance on infrastructure repairs, removing debris, and restoring power to communities.[118] In Japan, the JSDF has provided direct

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[117] For an excellent and comprehensive discussion of how the U.S. military supports HA/DR operations, see Ed McGrady, Maria Kingsley, and Jessica Stewart, *Climate Change: Potential Effects on Demands for US Military Humanitarian Assistance and Disaster Response*, (Arlington, VA; Center for Naval Analysis, November 2010), https://apps.dtic.mil/sti/pdfs/ADA564975.pdf.

[118] Brian La Shier and James Stanish, "Issue Brief: The National Security Impacts of Climate Change," *Environmental and Energy Study Institute*, December 20, 2017, https://www.eesi.org/papers/view/issue-brief-the-national-security-impacts-of-climate-change#:~:text=These%20risks%20are%20crop%20insurance,the%20impacts%20of%20climate%20change.

support for disaster relief operations increasingly often and for longer periods as storms appear to be becoming more severe and frequent. The JSDF has also long contributed to HA/DR efforts overseas, including, e.g., aiding flood victims in Djibouti in 2019 and assisting Australia in fighting huge bush fires in 2021.

Several points should be borne in mind, however, regarding the increased use of the military for HA/DR operations. Military units do not normally train specifically for HA/DR operations since their primary mission must remain defending their country's territory and interests. U.S. large-scale HA/DR operations, for example the 2004-2005 post-tsunami HA/DR operations in the Indian Ocean, have generally been *ad hoc*. If a country explicitly determines, however, that its military should assume primary responsibility for such HA/DR operations and therefore dedicate sufficient resources and training time to it, those will necessarily compete with the time and resources dedicated to preparations to defend the homeland, thus at a cost to combat readiness. As an example, the U.S. Navy's 2007 "Cooperative Strategy for 21st Century Seapower" added HA/DR (and maritime security) as a primary mission to the four traditional missions directly associated with being able to prevail in a conflict should one arise, based on the premise that "preventing wars is as important as winning wars."[119] The resources required to do the first would come at the cost, to some degree, of those required for fighting a conflict should one start. Under budgetary pressures, the U.S. Navy has since reverted to its four traditional primary missions.

Apart from domestic HA/DR operations, the militaries of more advanced countries will undoubtedly be called upon to assist in large-scale HA/DR operations overseas. Many areas of the western Pacific Ocean and the Indian Ocean are among those most prone to be hit by severe storms, wide-area flooding, or other climate change-attributable disasters. At the same time, many of the coastal countries in those regions are among the poorest and least able to handle large-scale disasters. Thus, it will be the collective responsibility of the wealthy, more advanced states to support less-developed nations struck by disaster, again generally with their military forces as the only organizations able to conduct the complex short-notice operations required to save lives and prevent further catastrophic consequences. As examples, in recent years, militaries around the world have been called upon to support disaster relief, including the recent responses to the 2019 heavy rains in Djibouti, the 2020 Australian bushfires, and the 2020 tropical cyclones in the Philippines.

Air and naval units are generally the assets used to conduct overseas HA/DR operations. Airlift is the fastest means to supply initial aid but is necessarily limited in terms of cargo capacity and depends critically on runways being available in the disaster area, which is not always the case. Naval ships have far greater relief supply capacity, and their helicopters, especially heavy-lift variants, are critical to delivering those supplies (and medicines) to hard-to-reach areas if transportation infrastructure in the disaster area has been destroyed or severely damaged. But those ships require significant logistics support both to refuel and resupply themselves, and to receive and distribute a constant flow of new relief supplies to keep the HA/DR operations going.

Besides direct HA/DR support, more advanced militaries and paramilitaries can also help build the HA/DR capacities of poorer states highly vulnerable to climate change-attributable disasters through

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[119] *A Cooperative Strategy for the 21st Century*, U.S. Department of the Navy, October 2007, https://www.hsdl.org/?view&did=479900.

recurrent bilateral or multilateral training with those nations' forces. This has the additional benefit of familiarizing the assisting nations' forces with local conditions (the "operating environment") and with the civil and possibly military authorities in the receiving nation that will need to be coordinated with during HA/DR operations.[120]

Peacekeeping Operations (PKO)

United Nations PKOs are conducted in order to help countries transition from conflict to peace. Most of the situations wherein the UN has conducted or is conducting PKOs involve open fighting between states or tribal/ethnic groups.[121] The *Net Zero 2050* report suggests that in the future there will be increasing numbers of conflicts whose underlying causes are effects attributable to climate change rather than conflicts generated primarily over political differences.

Some of the most pressing security threats generated by climate change will come from major disruptions to social systems. As the number and intensity of extreme weather events increase, the second- and third-order effects on food and water supplies may have compounding humanitarian consequences. Climate change touches every sector and region across the world, but as noted above, its impacts will be most acutely felt by developing countries, which often lack the resources necessary to effectively respond. This lack of capacity to mitigate the effects of global warming, either before disasters strike or in remediating their consequences, may increase the potential for competition and internal instability in these countries, especially over finite and perhaps shrinking resources.[122] The heightened pressure on already tenuous food and water supplies from more frequent and intense droughts and/or floods will likely have a cascading effect, triggering large-scale human migrations.[123] In 2020, 30 million people were internally displaced by climate-related weather events, three times more than those displaced by conflict (9.8 million).[124]

The erosion of coastlines and rising sea levels will also lead to displacement of large populations, which can create the conditions for political instability in countries as they may become overwhelmed by the influx of refugees and inability to care for them. When the Horn of Africa was struck with a regional drought in 2011, the Al-Shabaab insurgent group used water as a political weapon, cutting off cities from their already limited water sources. This led to hundreds of thousands of people being forcibly displaced.[125] Unlike war refugees who may be able to return to their homes in the future, environmental refuges are more likely to suffer permanent displacement.

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[120] For example, prior to the massive 2004-05 post-tsunami HA/DR operations, U.S.-Indonesian relations had been very strained. U.S. forces delivering medicines and relief supplies to isolated areas of Sumatra were required to be off Indonesian territory by sunset each day. Coordination with Indonesian civil authorities was critical to the success of the HA/DR efforts.

[121] See https://www.unmissions.org/ and https://peacekeeping.un.org/en/past-peacekeeping-operations.

[122] Office of the Director of National Intelligence (ODNI), *Annual Threat Assessment of the US Intelligence Community* (Washington, DC: Director of National Intelligence, April 2021), p. 18.

[123] C. Mbow, C. Rosenzweig, L.G. Barioni, T.G. Benton, M. Herrero et al., "Food Security," in *Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*, ed. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Portner et al, (2019), p. 516.

[124] "Displacement in a Changing Climate: Localized Humanitarian Action at the Forefront of the Climate Crisis," *International Federation of the Red Cross*, 2021, https://www.ifrc.org/sites/default/files/2021-11/2021-Climate-Displacement-Report-Final.pdf, p. 9.

[125] Caitlin E. Werrell and Francesco Femia, *Epicenters of Climate and Security: The New Geostrategic Landscape of the Anthropocene,* (Washington, D.C.: Center for Climate and Security, 2017), p. 69.

As climate change continues, the mounting physical effects will likely require countries to increase their reliance on military forces to stem or control mass population movements and/or provide security for refugees who may be confined for prolonged periods in temporary or makeshift living conditions. Unfortunately, in many cases, the countries most likely to suffer such disasters are also those least likely to have adequate political leadership or sufficient capable military or paramilitary forces to conduct such activities. Thus, international organizations, especially the UN, likely will have to step in to try to prevent or to deal with the aftermath of disasters.

United Nations PKOs support countries in protecting civilians, preventing or limiting conflicts, reducing cross-border violence, and strengthening security and the rule of law.[126] But as the physical effects of climate change lead to more frequent instability and outbreak of conflicts, the number of UN PKOs, currently twelve, will very likely increase significantly in both number and scope. In 2020 alone, six of the ten largest UN-led PKOs were in countries that are most exposed to climate change.[127] Several of the current UN PKOs are occurring in countries that are engaged or threatened by conflict over resources, some of which, e.g., food and water, are directly affected by global warming. This is not new in a sense, but the intensity and frequency of such conflicts will grow as the rate and extent of climate change increases.

Implications

Over the next 40 years, the frequency of military support in HA/DR operations will increase as the frequency of climate-related natural disasters and weather events increases.[128] Requiring militaries to respond to concurrent and frequent HA/DR or PKOs, on top of their current mission requirements, may lead to compounding risks, including stretching logistics resources and the readiness to address other contingencies.[129] As support vessels and air assets are committed to more frequent HA/DR missions, militaries risk these assets being unavailable for other missions. Militaries may also see faster-than-planned-for consumption of expected service life for expensive military assets for non-military taskings. To increase capacity, militaries may have to invest in more logistics and search-and-rescue assets and increase personnel at the cost of spending more money in the near-term to hedge against longer-term risks. Absent such greater investment, militaries can expect to pay higher operating costs to maintain high-use assets and to keep personnel operating at higher operational tempos.[130]

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[126] "What We Do," United Nations Peacekeeping, https://peacekeeping.un.org/en/what-we-do.

[127] Cedric de Coning, Florian Krampe, and Jake Sherman, "Emerging Lessons from Implementing Climate-Related Peace and Security Mandates," *IPI Global Observatory*, April 20, 2021, https://theglobalobservatory.org/2021/04/emerging-lessons-implementing-climate-related-peace-security-mandates/.

[128] Samir Sebbah, Abdeslem Boukhtouta, Jean Berger, and Ahmed Ghanmi, "Military Logistics Planning in Humanitarian Relief," in *Humanitarian and Relief Logistics*, ed. V. Zeimpekis, S. Ichoua, I. Minis, Operations Research/Computer Science Interfaces Series, vol 54, (New York: Springer, 2013).

[129] Lucia Retter, Anna Knack, Zudik Hernandez, Ruth Harris, Ben Caves et al, *Crisis Response in a Changing Climate: Implications of Climate Change for UK Defence Logistics in Humanitarian Assistance and Disaster Relief (HADR) and Military Aid to Civil Authorities (MACA) Operations* (Santa Monica, CA and Cambridge, UK: RAND Corporation, 2021), p. 18.

[130] Japan's current Minister of Defense has also addressed the potential readiness issue JSDF faces as climate change progresses, stating, "…increases of climate change-induced natural disasters have a potential to adversely impact the capacity of Japan Self-Defense Forces." See Nobuo Kishi, Minister of Defense, "Climate Security Session: Leaders Summit on Climate," *Ministry of Defense*, April 23, 2021, https://www.mod.go.jp/en/article/2021/04/a88c937c30be56316213265a47eaccf669dc8ff4.html.

Anti-Terrorism/Anti-Piracy Operations

Apart from instability or conflict due to internal ethnic and/or tribal conflicts, the most under-developed and impoverished countries also tend to be those poorly endowed with natural resources (often a primary driver of the instability or conflict), particularly food and water. Consequently, they are also those likely to be among the worst affected by climate change as such shortages become more acute as a result. At times in the past, this has led to establishment of terrorist groups such as Al-Shabaab, which can concurrently take advantage of poor conditions as well as further aggravate them. In some cases of extreme poverty, piracy has reemerged as a threat. These threats were well-illustrated over the past 2-3 decades in places like the Horn of Africa or the Gulf of Guinea.

This has had significant implications for, especially, naval forces. For example, major anti-piracy operations had to be conducted for years in the Gulf of Aden and the Eastern Arabian Sea against pirates operating from Somalia and Somaliland. Conducting hundreds of attacks per year at their height, pirates threatened high density shipping lanes. As a consequence, NATO established and maintained a naval task group in the region for many years, and individual countries including India, China, and Japan contributed warships as well in order to maintain maritime security, with a JMSDF officer serving as the task group commander in 2015.[131] This entailed expensive employment and logistical sustainment of naval assets far from their home bases, while making them unavailable for their principal defense missions.

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[131] "Japan Makes History as it Takes the Lead of Combined Task Force 151," *Combined Maritime Forces (CMF)*, June 2, 2015, https://combinedmaritimeforces.com/2015/06/02/japan-makes-history-as-it-takes-the-lead-of-combined-task-force-151/.

CHAPTER 4

Limiting Climate Change

Energy Transition

The *Net Zero 2050* report argues that successfully mitigating climate change by limiting warming to 1.5ºC by 2050 will require NZE to be achieved by that year. This will entail a move away from fossil fuels to other energy sources.

The move toward NZE by 2050 will require a major transition from fossil fuels to renewable or alternative non-emitting (e.g., nuclear power) for energy production. The energy sector currently accounts for roughly ¾ of total global greenhouse gas emissions.[132] To help slow the effects of climate change and reduce emissions, many countries around the world have started, albeit slowly, to transition to renewable or non-emitting energy sources and concomitantly lessen their reliance on fossil fuels. In the IEA's scenario, the path to 1.5°C temperature rise relies on renewable energy supplying between 70-85 percent of electricity by 2050, with two-thirds of electricity generation coming from wind, solar, bioenergy, geothermal, and hydro energy.[133] To make this a reality, the transition to non-fossil fuel energy will be dependent on the pace of technological development, individual country investments, and the availability of key resources and raw materials.

As noted previously, hydropower has been a leading source of renewable energy over the past several decades. But to limit global warming to 1.5°C, *Net Zero 2050* states that expansion of wind and solar power will be critical. With solar power leading the way—accounting for 20 percent of energy supplies in 2050—the growth of wind and solar capacity could triple renewable energy generation by 2030 and increase it by more than eight times by 2050.[134] This all depends on the ability and willingness of countries to rapidly scale up the required investments in solar and wind power generation infrastructure and technology within the next decade. Although wind and solar power are some of the

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[132] Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021), p. 13.

[133] Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018), p. 15; Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021), p. 18.

[134] Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021), p. 18, 73.

most affordable forms of energy generation to incorporate into a country's existing electricity grid, rapidly expanding them, however, relies heavily on the supply chains for critical resources.[135]

A critical feature of both wind and solar power is that they are heavily weather-dependent. Thus, the power they are able to generate in particular locations on given days may fluctuate considerably. During cloudy days solar power generation will wane, while wind power generation obviously cannot occur when it is insufficiently windy. One area of significant uncertainty regarding wind-generated energy is the potential effect of global warming on mean global and regional wind speeds.[136] A related area of uncertainty concerns climate change-induced significant changes in global wind patterns, which could have substantial implications for, e.g., weather patterns, agriculture, and desertification.[137] As long as the uncertainty about and/or volatility of future wind patterns in different geographic regions and globally remains unclear, that has obvious implications for the willingness or ability to make significant investments in large-scale, high capacity wind power projects.

In practical terms, this means that solar and wind power generation systems will make variable contributions to supplying electricity to the larger electrical grid for a given geographic area or location. On days when their power generated falls below electricity demand, back-up systems will be required to make up the difference. On other days, wind and solar power systems may generate excess electricity, which is either lost or which will have to be stored, generally in high-capacity batteries. The technologies for creating those either does not yet exist, or else is not presently cost-effective or available on the scales required.

The transportation sector is projected to become among the largest users of electrical power, especially as various countries as well as U.S. states seek to make driving fossil-fuel powered cars and trucks ever costlier to acquire and operate in order to incentivize a wholesale shift to electric vehicles.[138] Besides creation of a large support infrastructure to recharge millions of vehicles, those vehicles will also require technologically-sophisticated batteries in order to achieve practical ranges per recharge. These batteries will have to be produced in very large numbers.

In short, development of the necessary battery technologies and their mass production on a large scale will be a significant factor in the transition from fossil fuels. As will be discussed further, this will also have substantial consequences that go beyond just electricity generation and consumption.

One other alternative non-emitting power generation source is nuclear power. Nuclear reactors generally run on uranium or plutonium, or in rare cases, thorium in conjunction with recycled

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[135] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 3.

[136] See, for example, Chelsea Harvey, "The World's Winds Are Speeding Up," *Scientific American*, November 19, 2019, https://www.scientificamerican.com/article/the-worlds-winds-are-speeding-up/; but, in contrast, Isabel van Halm, "Weekly data: Changes in wind speed caused by climate change may affect future wind power output," *Energy Monitor*, November 22, 2021, https://www.energymonitor.ai/finance/risk-management/weekly-data-changes-in-wind-speed-caused-by-climate-change-may-affect-future-wind-power-output

[137] Marie Aronsohn, "Will Global Warming Bring a Change in the Winds? Dust from the Deep Sea Provides a Clue," Columbia University Climate School, January 6, 2021, https://news.climate.columbia.edu/2021/01/06/westerly-winds-climate-change/.

[138] The share of total energy consumption by the U.S. transportation sector has consistently been 26-30% since 2000. See *U.S. Energy Consumption by the Transportation Sector*, U.S. Bureau of Transportation Statistics, https://www.bts.gov/content/us-energy-consumption-transportation-sector.

plutonium. Though in use for decades in many countries, various concerns such as safety issues, environmental concerns, proliferation fears, public hostility, and regulatory delays have made it ever more costly to build and maintain nuclear power reactors. There is, however, considerable developmental work being done to create new kinds of far safer reactors, such as small modular reactors.

Electric Vehicles (EV)

A critical component of reaching NZE by 2050 is the switch from internal combustion engines to EVs, given the huge extent of transportation sector energy consumption and its criticality for other sectors of economies. Per the *Net Zero 2050* report, EVs are projected to go from roughly 5 percent of current global vehicle sales to more than 60 percent by 2030.[139] To be achievable, this rapid increase will require an immediate scaling up of supply chains for batteries, as well as the charging infrastructure necessary to keep them charged. This means the supply of lithium, cobalt, nickel, and manganese for the battery cathodes and of graphite for their anodes will need to rapidly increase to meet the future market demand.[140] However, a key challenge to scaling up production is that many of these elements necessary to produce EV batteries are concentrated in only a handful of countries, with more than 70 percent of production capacity located in China.[141] Of these critical minerals, China leads the world as the main supplier of graphite at 79 percent of global production, with the Democratic Republic of Congo (DRC) responsible for producing nearly 70 percent of the world's cobalt supply. [142] But of the DRC's 19 cobalt-producing mines, Chinese-backed companies own or have financial stakes in 15.[143] In 2019, of the 70 lithium battery mega-factories under construction, 46 were located in China.[144] China's efforts over the last two decades have enabled it to exert significant control on supplies and prices of rare earths.[145] However, countries like the United States and Japan have taken steps to mitigate this risk.[146]

If no major market changes occur in production of these elements, in most cases countries will be forced to rely on single-source suppliers. The greater the demand for more EVs, the greater the

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[139] Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021), p. 14.

[140] Simon Moores, Managing Director of Benchmark Mineral Intelligence, "Testimony before the Senate Committee on Energy and Natural Resources, Hearing on the Outlook for Energy and Minerals Markets," February 5, 2019.

[141] "Trends and Developments in Electric Vehicle Markets," *International Energy Agency,*" 2021, https://www.iea.org/reports/global-ev-outlook-2021/trends-and-developments-in-electric-vehicle-markets.

[142] Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021), p. 159; Isabeau van Halm and Cathy Mullan, "Booming EV Sales Challenge Critical Mineral Supply Chains," *Energy Monitor*, February 14, 2022, https://www.energymonitor.ai/sectors/transport /booming-ev-sales-challenge-mineral-supply-chains.

[143] Eric Lipton and Dionne Searcey, "Chinese Company Removed as Operator of Cobalt Mine in Congo," *The New York Times*, February 28, 2022, https://www.nytimes.com/2022/02/28/world/congo-cobalt-mining-china.html#:~:text=As%20of%202020%2C%20Chinese%2Dbacked,fail%20to%20benefit%20the%20Congolese.

[144] Simon Moores, Managing Director of Benchmark Mineral Intelligence, "Testimony before the Senate Committee on Energy and Natural Resources, Hearing on the Outlook for Energy and Minerals Markets," February 5, 2019.

[145] Keith Bradsher, "Amid Tension, China Blocks Vital Exports to Japan," September 22, 2010, *New York Times*, https://www.nytimes.com/2010/09/23/business/global/23rare.html.

[146] Samantha Subin, "The new U.S. plan to rival China and end cornering of market in rare earth metals," *CNBC*, April 17, 2021, https://www.cnbc.com/2021/04/17/the-new-us-plan-to-rival-chinas-dominance-in-rare-earth-metals.html; Mary Hui, "Japan's global rare earths quest holds lessons for the US and Europe," April 23, 2021, *Quartz*, https://qz.com/1998773/japans-rare-earths-strategy-has-lessons-for-us-europe/; "FACT SHEET: Securing a Made in America Supply Chain for Critical Minerals," *The White House*, February 22, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/02/22/fact-sheet-securing-a-made-in-america-supply-chain-for-critical-minerals/.

pressure on the supply chains. As a consequence, the cost to produce EVs is projected to surge by 22 percent between 2023 and 2026, primarily due to the scarcity of the key elements necessary for the battery cells.[147]

There are several potential measures to ease such supply chain constraints. The need to increase manufacturing capacity is apparent, with several solutions already being developed so countries can rely less on the abovementioned key minerals. For example, General Motors is developing batteries that will require 70 percent less cobalt in order to shorten that supply chain.[148] There is also continuing exploration for new deposits of critical elements that may be found and mined in areas outside of China, the DRC, or other suppliers having semi-monopolistic control over scarce resources. For example, an untapped deposit of iron, copper, cobalt, and lithium in Afghanistan worth nearly $1 trillion was located in 2010.[149] The difficulty is that new deposits could take years to see any return on investment, as it can take decades to develop a mining industry in locations with little to no infrastructure already in place, while political difficulties, including internal conflicts, may seriously delay or restrict such development.

Rare Earths

The path forward in the IEA's NZE scenario requires a considerable increase in demand for critical minerals such as copper, lithium, nickel, cobalt, but especially rare earth elements.[150] The demand for rare earths, specifically, will increase by a factor of ten by 2030.[151]

As countries reduce fossil fuel consumption and transition to cleaner energy sources, they will also need to consider the competition for and access to limited mineral resources such as rare earths necessary to develop the technology to mitigate global warming. Specifically, as the transition from fossil fuels gets underway countries can expect to increasingly compete over controlling the market for the rare earth minerals essential for clean energy sources.[152] China is currently in one of the best positions to compete in the rare earth market, controlling more than 50 percent of the global processing capacity for rare earths used in wind turbines and key components of electronic and electrical systems, polysilicon for solar panels, and lithium used for EV batteries.[153] The EV market is

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[147] Phil LeBeau, "EV Battery Costs Could Spike 22% by 2026 as Raw Material Shortages Drag On," *CNBC*, May 18, 2022, https://www.cnbc.com/2022/05/18/ev-battery-costs-set-to-spike-as-raw-material-shortages-drags-on.html.

[148] Isabeau van Halm and Cathy Mullan, "Booming EV Sales Challenge Critical Mineral Supply Chains," *Energy Monitor*, February 14, 2022, https://www.energymonitor.ai/sectors/transport/booming-ev-sales-challenge-mineral-supply-chains.

[149] James Risen, "U.S. Identifies Vast Mineral Riches in Afghanistan," *The New York Times*, June 13, 2010, https://www.nytimes.com/2010/06/14/world/asia/14minerals.html.

[150] The rare earth elements (REE) are a set of seventeen metallic elements. These include the fifteen lanthanides on the periodic table plus scandium and yttrium. Rare earth elements are an essential part of many high-tech devices. See https://www.americangeosciences.org/critical-issues/faq/what-are-rare-earth-elements-and-why-are-they-important

[151] Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021), p. 162.

[152] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 6.

[153] Ibid. .

especially reliant on rare earths, with their batteries requiring six times more of them than do conventional vehicles.[154]

Due to China's current dominance in the market for these minerals, other countries face the risk of becoming reliant on it as a single supplier if they wish to incorporate renewable energy into their electricity grids. As stated by Simon Moores, the current Chief Executive Officer of Benchmark Mineral Intelligence, "Those who control these critical raw materials and those who possess the manufacturing and processing know how, will hold the balance of industrial power in the 21st century auto and energy storage industries."[155]

Currently, the competition for rare earths is limited to supply chain access rather than physical possession of them. In the future, countries may also have to consider how they will ensure stable and reliable access to these key minerals if a major crisis or conflict were to break out. A crisis involving a country where rare earths are heavily concentrated may well hinder that country's ability to export those elements, starving other countries of critical materials needed to employ clean energy technologies. Looking to the future, nations will need to ensure there is flexibility in the available supply chains for these critical materials to hedge against supply shortages or exorbitant price hikes, including perhaps building stockpiles of strategic materials to hedge against supply interruption .

In short, as they transition to cleaner energy technology, states must be mindful that they are not replacing their current reliance on fossil fuels with a new dependence on critical rare earth minerals and other key elements.

Charging Infrastructure

To successfully switch from internal combustion engine vehicles to EVs, countries will need not only to invest in the critical resources needed for batteries, but also in the recharging infrastructure necessary to support mass use of EVs. A robust, resilient network of charging stations, both in private residences and in public stations, will be necessary to support the NZE goal. As EV charging infrastructure is built out, most EV charging stations will be in private residences, with six in ten charging sessions forecasted to take place at home or at work.[156] Using the United States as an exemplar, on mean each person travels roughly 30 miles each day by vehicle. The range of newer EV models is over 200 miles before another charging is required.[157] Although EV models can travel the distances of the mean person without needing a re-charge, the bigger question is how many public EV charging stations will be necessary to support other consumers. While most charging stations will be installed at homes, there will still be a requirement for public charging stations.[158]

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154 Isabeau van Halm and Cathy Mullan, "Booming EV Sales Challenge Critical Mineral Supply Chains," *Energy Monitor*, February 14, 2022, https://www.energymonitor.ai/sectors/transport/booming-ev-sales-challenge-mineral-supply-chains.

155 Simon Moores, Managing Director of Benchmark Mineral Intelligence, "Testimony before the Senate Committee on Energy and Natural Resources, Hearing on the Outlook for Energy and Minerals Markets," February 5, 2019.

156 Philipp Kampshoff, Adi Kumar, Shannon Peloquin, and Shivika Sahdev, "Building the Electric-Vehicle Charging Infrastructure America Needs," *McKinsey & Company*, April 18, 2022, https://www.mckinsey.com/industries/public-and-social-sector/our-insights/building-the-electric-vehicle-charging-infrastructure-america-needs.

157 Ibid.

158 Ibid.

People living in apartments will be more dependent on public charging stations, as will those who live in the country or are commercial vehicle drivers who must travel longer distances. One of the downsides to public chargers, however, is their cost. Compared to charging at home, using electricity from a public charge station can cost up to five to ten times as much.[159] When building EV infrastructure, countries must also consider the larger cost of upgrading power grids to supply enough electricity to meet EV charging demands. Direct current (DC) fast chargers, which allow drivers to recharge 80 percent of their vehicle's battery in 30 minutes, can cost between $125,000 and $300,000.[160]

The creation of a robust national battery-charging infrastructure will also bring with it new vulnerabilities. Cyberattack poses a major security risk. As more EVs and their corresponding recharging networks incorporate digitalized monitoring and controls, this will create new attack vectors for computer criminals to exploit. Hacking into EV infrastructure is becoming more commonplace, with a recent incident occurring in Russia when Ukrainian programmers hacked into charging stations to display anti-war messages.[161] In the future, hackers looking to make a profit may target EV recharging stations, slowing, or even shutting down the chargers until a ransom fee is paid. With EV infrastructure already falling behind the build-out rate needed to meet anticipated future consumer demand, cyberattacks could prove highly disruptive if significant numbers of recharging locations are held to ransom.

Developing Country Infrastructure

The budgetary demands to mitigate climate change are immense and far reaching. Today, the overall cumulative cost of economic damage related to climate change is estimated to be $54 trillion by 2100 if warming is maintained to 1.5°C, and $69 trillion at 2°C.[162] Rising sea levels, alone, are one of the greatest drivers of future cost, with, as an example, 23 East Asian coastal cities having a total of 12 million people and a combined $864 billion in assets being exposed to potential loss from weather events made more severe as a consequence of higher sea levels.[163]

More extreme rainfall and heat will also raise the cost of maintaining and/or repairing current civilian and military infrastructure. Future population growth coupled with a warming climate will lead to a higher demand for energy. Hotter temperatures will mean more air-conditioning, placing increased strain on power plants to meet the demand.[164] Even as countries switch to renewable energy, the demands for hydropower, solar, and wind power will continue to increase as global warming continues.

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[159] Ibid..

[160] Morgan Korn, "More EVs are Coming. Where's the Infrastructure to Support Them?" *ABC News*, December 5, 2021, https://abcnews.go.com/Business/evs-coming-infrastructure-support/story?id=81502192.

[161] Michael Butler, "Hackers are Starting to Target EV Charging Stations," *Carbuzz*, May 10, 2022, https://carbuzz.com/news/hackers-are-starting-to-target-ev-charging-stations.

[162] Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018), p. 264.

[163] Michael I. Westphal, Gordon A. Hughes, and Jörn Brömmelhörster, eds., "Economics of Climate Change in East Asia," *Asian Development Bank*, 2015, p. 61.

[164] Frank Ackerman and Elizabeth A. Stanton, "The Cost of Climate Change: What We'll Pay if Global Warming Continues Unchecked," *Natural Resources Defense Council*, May 2008, p. 9.

The likelihood of increasing drought conditions will also put additional limits on hydroelectric power plants, raising overall costs to simply keep the power on.

Beyond setting a target to limit global greenhouse emissions, the 2015 Paris Agreement also aimed to enhance the ability and capacity of developing countries to cut carbon dioxide levels.[165] To ensure countries meet the NZE goal by 2050, international cooperation between developed and developing countries will be critical. One obstacle in reaching NZE is the large amount of new infrastructure and modifications to existing assets required. Today, many emerging markets are reliant on public sources of finance to fund new renewable energy projects and facilities.[166] These projects can range from more efficient electricity networks to EV charging stations to new pipelines for low emission fuels.

Meeting developing countries' needs for financial and technological assistance towards renewable energy projects presents a medium risk of insufficiency today but will become a high risk by 2030.[167] The necessary financing is currently estimated at nearly $100 billion a year to allow those countries to adapt to climate change and will increase to $300 billion year by 2030.[168]

To help enable developing countries and emerging economies to adopt the necessary infrastructure to support renewable energy and reach NZE by 2050, developed countries like the United States and Japan can offer assistance through foreign direct investment (FDI). In the western Pacific region, focusing on developing countries in the Association of Southeast Asian Nations (ASEAN) and the Oceania region, the United States and Japan could use FDI to help improve their climate change resilience. Parenthetically, such relationships would also offer concurrent opportunities for agreements to allow military basing and/or access in the event of crisis or conflict. Host nations would benefit in that such basing or access would facilitate speedy HA/DR operations in the event of a natural disaster. The United States and Japan could also consider adding a dimension to future training and exercises that allows them to test and maintain the basing and access agreements that stem from such FDIs.

Weather Modification Techniques

The physical effects of climate change will require more effective water resource management, especially in regions already prone to more arid conditions. To make up for the shortage of rainfall, some countries are turning to weather modification techniques such as cloud seeding to trigger precipitation. Weather modification was experimented with as early as the 1940s. Scientists discovered that when cold material such as silver iodine crystals is dispersed into clouds, it can lead to ice crystal formation and precipitation in selected areas.[169] In 2020 alone, the United Arab Emirates oversaw

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[165] Valérie Masson-Delmotte, et al, "Global Warming of 1.5°C," *An IPCC Special Report on the Impacts of Global Warming of 1.5°C* 1, no. 5 (2018), p. 360.

[166] Stéphanie Bouckaert, Araceli Fernandez Pales, Christophe McGlade, Uwe Remme, and Brent Wanner, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (International Energy Agency, 2021), p. 154.

[167] "Climate Change and International Responses Increasing Challenges to US National Security Through 2040," NIC-NIE-2021-10030-A (Office of the Director of National Intelligence, 2021), https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf, p. 2.

[168] Ibid, p. 5-6.

[169] Lisa M.P. Munoz, "Seeding Change in Weather Modification Globally," *World Meteorological Organization Bulletin* 66, no. 1 (2017), https://public.wmo.int/en/resources/bulletin/seeding-change-weather-modification-globally.

more than 200 cloud seeding operations to spur rainfall.[170] China has also invested in similar efforts to trigger precipitation, beginning as early as the 1950s. Today, it spends about $200 million a year on its cloud seeding program to ensure crops and cities receive enough precipitation.[171]

Although countries have increasingly used similar weather modification techniques to affect atmospheric conditions to generate increased rainfall, not everyone agrees on the science behind the technique, with some arguing that it can be difficult to prove the causal relationship between increased rainfall and cloud seeding.[172] There are also risks to using weather modification techniques like cloud seeding, including unintended effects in areas other than the desired target region. For example, in the past Iran has accused Israel of stealing its water by using cloud seeding that resulted in reduced rainfall over Iranian territory.[173] In the face of climate change, weather modification techniques are just one tool of many. To truly limit the effects of rising global temperatures, reducing greenhouse gas emissions remains the first line of defense.

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[170] Christine Fernando, "Drones are Zapping Clouds with Electricity to Create Rain in United Arab Emirates Project," *USA Today*, July 21, 2021, https://www.usatoday.com/story/news/world/2021/07/21/cloud-seeding-uae-artificial-rain-drones-electricity/8040330002/.

[171] "No Silver Lining: Cloud-Seeding Will Not Solve China's Water Shortages," *The Economist*, March 25, 2021, https://www.economist.com/china/2021/03/25/cloud-seeding-will-not-solve-chinas-water-shortages.

[172] Ibid.

[173] Tracy Raczek, ""Geoengineering: Reining in the Weather Warriors," *Chatham House*, February 15, 2022, https://www.chathamhouse.org/2022/02/geoengineering-reining-weather-warriors.

CHAPTER 5

Final Thoughts

This report has provided a broad *tour d'horizon* of likely or possible impacts of various kinds that could result from climate change if the assumptions made in the IEA's *Net Zero 2050* report prove to be accurate. Many of the report's trends and projections make for sobering reading, even in the 1.5°C global mean temperature rise scenario. As suggested in Figure 1, these impacts could be considerably worse in many ways if a 2.0°C temperature rise occurred.

These trends and projections were premised on the four main assumptions listed in Chapter 1. It should be noted that all four assumptions are very robust, i.e., they are exceptionally optimistic with regard to the likelihood of them actually being accurate. The IEA researchers made those assumptions in order to have an initial analytic foundation for their work. They were essentially seeking to demonstrate that achieving net zero emissions by 2050 is possible in the physical science context, if it assumed that the necessary political measures and cooperation were undertaken by all members of the international community.

However, this may be a classic case of the "tragedy of the commons," where individual states are the principal actors.[174] If the report's main assumptions prove to be highly optimistic (or unrealistic), then the consequences of climate change that the report describes could be substantially understated. It may be a worthwhile "thought experiment" for researchers to consider the case if those assumptions were reversed, i.e., read as follows:

- *Not* all countries will cooperate towards achieving net-zero emissions worldwide (including some of the greatest CO_2 emitting countries);
- Countries that do not cooperate towards net-zero emissions will *not* be offset by corresponding adaptation measures from the other countries;

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[174] The "tragedy of the commons" refers to an economic theory in which individuals with access to a public resource (also called a common) act in their own interest and, in doing so, ultimately deplete the resource (or in the case of climate change, are unable to achieve the end goal of net zero emissions). See Alexandra Spiliakos, "Tragedy of the Commons: What It Is and 5 Examples," February 6, 2019, *Harvard Business School Online*, https://online.hbs.edu/blog/post/tragedy-of-the-commons-impact-on-sustainability-issues.

- The transition across the energy sector towards low-carbon emissions and renewable energy sources will *not* be orderly, and instead will be more episodic, semi-chaotic, or "Darwinian" for various reasons; and

- The deployment of more energy-efficient technologies and the growth of renewables that could play a central part in reducing emissions will be slow, uncoordinated, and uncertain.

If for argument's sake, these "pessimistic" assumptions were made, they would lead to far more severe, and largely unknowable, consequences for the future geophysical and security environments than even the 2°C temperature rise case is projected to be by the NIC and IPCC in Figure 1. Clearly, what the "worst case" could turn out to be would necessarily be highly speculative, and thus of limited value to try to analyze.

What would be useful analytically, however, is for climate researchers to do "sensitivity analyses" on each of the above assumptions. That is, researchers could establish gradations of each assumption to reflect various political, diplomatic, economic, and scientific sub-assumptions. They could then assess the potential impacts and consequences of different mixes of the four key assumptions. The overall objective would be to see whether and how those main assumptions (and sub-assumptions) could be affected positively through active measures and actions by states and international organizations.

LIST OF ACRONYMS

ASEAN	Association of Southeast Asian Nations
CAR	Central Arctic Route
CSBA	Center for Strategic and Budgetary Assessments
DoD	U.S. Department of Defense
DRC	Democratic Republic of the Congo
EEZ	Exclusive Economic Zone
EV	Electric Vehicle
FDI	Foreign Direct Investment
GMSL	Global Mean Sea Level
HA/DR	Humanitarian Assistance/Disaster Response
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JMSDF	Japanese Maritime Self-Defense Force
JSDF	Japanese Self-Defense Force
LEO	Low-Earth Orbit
MOFA	Ministry of Foreign Affairs
NATO	North Atlantic Treaty Organization
NIC	National Intelligence Council
NIE	National Intelligence Estimate
NSR	Northern Sea Route
NWP	North-West Passage
NZE	Net Zero Emissions
PKO	Peacekeeping Operations
PLA	People's Liberation Army
PSR	Polar Silk Road
TSR	Transpolar Sea Route
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
USGS	United States Geological Survey
ZNE	Zero Net Emissions