Fifth National Climate Assessment: Chapter 17

Climate Effects on US International Interests

Chapter 17. Climate Effects on US International Interests

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Introduction

Globally, climate change is rapid and widespread and will continue through midcentury even if emissions are cut sharply, intensifying events such as extreme heatwaves, heavy rainfall, and drought.[1] The acute and accelerating impacts outside of US borders on food systems, health, human well-being, built and natural systems, and economic sectors[2] affect US national interests and compound the impacts of warming within the United States. The pace of emissions reduction and adaptation response would need to accelerate this decade both to limit warming to 1.5°C (2.7° F) or 2°C (3.6° F) above preindustrial levels and to build resilience to existing and future climate impacts (KMs 2.3, 32.1).[2,3]

In a globally connected world, climate impacts can affect multiple sectors at once and have cascading effects that cut across sectors and geographies (KM 17.1). The direct impacts of climate change globally on people, ecosystems, and infrastructure, as well as the global transition to cleaner, lower-emissions technologies and economies, affect critical US interests including national security (KM 17.2); economics, trade, and investment (KM 17.3); and sustainable development (KM 17.4).

Despite documented evidence of increasing climate change risks, mitigation and adaptation responses by public and private sectors are not yet sufficient to avoid rising losses of life, biodiversity, infrastructure, and economic opportunity.[1,2] Proactive early adaptation and mitigation action can reduce losses from climate change and extreme events, avoid locking in high emissions, and produce economic, social, and environmental benefits.[4] In particular, inclusive approaches can help reduce risks, improve effectiveness of responses, and create opportunities for Indigenous Peoples, local communities, and other marginalized and underrepresented populations (such as women, youth, older adults, and ethnic minorities) who are especially vulnerable to climate impacts and energy transitions (KM 31.2). Adapting to a changing climate depends in part on the effective integration of climate information into decision-making at global, regional, national, and local levels (Box 17.1; KM 31.4).

Box 17.1. Climate Services at the International Level

Risk governance in the 21st century requires coherent actions across disaster risk reduction and climate change adaptation.[5,6] Systematic, coordinated approaches to climate information services (hereafter "climate services") can enable the development, quality-assurance, accessibility, stakeholder engagement, and knowledge-tailoring needed to support decision-making, from disaster risk reduction to resilient infrastructure development.[7,8,9] Climate services involves organizing different types of climate information (e.g., extreme-event return periods, slow onset trends such as sea level rise, in situ risk mapping, satellite-based data) across multiple timescales (e.g., weeks, seasons, decades, and longer), as well as technical assistance to help decision-makers interpret and integrate such information and related uncertainties into their planning and design processes. Such services support the coordination and implementation of international instruments and frameworks in which the United States has strong interests, including the Paris Agreement on climate change, the Sendai Framework for Disaster Risk Reduction 2015–2030, and the United Nations Sustainable Development Goals. Climate services are a central pillar of both the US President's Emergency Plan for Adaptation and Resilience (PREPARE), and the United Nations Secretary-General's initiative on Early Warnings for ALL (EW4ALL), launched in 2022. The EW4ALL goal is to ensure global coverage of action-oriented information systems to anticipate and reduce weather- and climate-related disasters by 2027.

There has been notable recent progress in data availability, including satellite-based information, climate- and disaster risk–related analytics, and networks for engaging communities across sectors such as national security, humanitarian interventions, water resources, human health, energy, food security, and infrastructure planning.[2,10,11,12] Examples include the Global Framework for Climate Services (GFCS), the European Union Copernicus Climate Change Service, Enhancing National Climate Services, and the Famine Early Warning Systems Network. The GFCS was initiated in 2009 and formally endorsed by the 187 member countries of the World Meteorological Organization, including the US.[8] However, many regions and countries lack sufficient capacity to assess climate impacts and cascading risks and to develop and deliver climate services to inform their immediate risk management and longer-term resilience goals.[13,14,15,16,17] While fundamentally important, observing networks are often inadequate in many regions. Many countries also lack comprehensive data on the local-level impacts of climate extremes and changes, hampering effective co-development and sustained delivery of services (KMs 31.3, 31.4; Ch. 23).[18] These gaps can undermine confidence in national and international climate service providers, sending users in search of alternative, competing, and less authoritative services, and, critically, can increase marginalization and inequity.

Key Message 17.1

Interdependent, Systemic Climate-Related Risks Increasingly Affect US Interests

In a globally connected world, climate change impacts on US interests are multifaceted, interconnected, and frequently exacerbated by social unrest and environmental degradation (*likely*, *high confidence*). The scale and speed of climate-related impacts to US interests are expected to increase, due in part to underlying interdependencies and to the projected intensification of climate change (*likely*, *high confidence*). Emerging systems- and scenarios-based approaches to integrative planning are being applied to account for interdependencies and competing priorities (*likely*, *high confidence*).

Climate-related risks manifest across multiple systems, sectors, geographic domains, and timescales.[19,20] Climate shocks in one or several parts of the built or natural system can lead to ripple effects around the world.[21,22] Climate change impacts—alone or in combination with compounding stressors—can cascade across interdependent systems, magnifying risks not typically attributed to climate change. The effects of these impacts can spill across geographies and markets and, in turn, affect multiple US security, economic, and sustainable development interests (Figure 17.1; Focus on Compound Events). Moreover, traditional approaches to managing risk are inadequate given the compound and cascading nature of system risk,

increasing the importance of accounting for system interdependency and uncertainty to reduce risk to US national interests.[23,24]

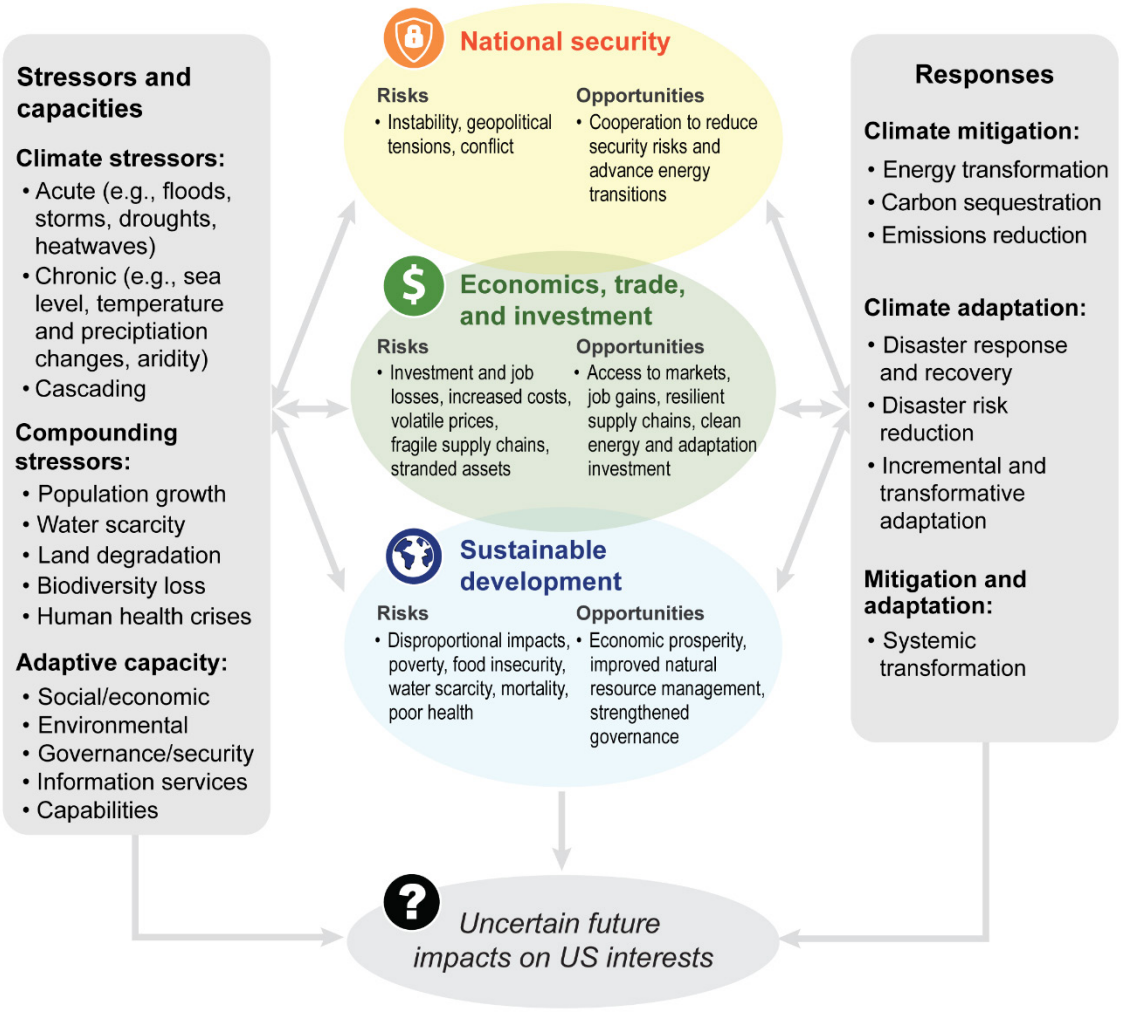
Climate change impacts affect the US's security, economy, and sustainable development interests by reducing local and global stability, disrupting livelihoods and economic growth, increasing poverty and global inequality[25,26] and compounding existing risks across US interests. For example, the Central American countries El Salvador, Guatemala, and Honduras are highly dependent on climate-sensitive agriculture, and climate change impacts disrupt rural livelihoods, health, and food security.[27] Drought and extreme storms have impacted millions of Central Americans by exacerbating conflict and insecurity, requiring significant humanitarian resources and fueling unprecedented migration, including to the United States.[28,29,30,31] Drought and extreme storms in Central America are expected to increase in frequency and severity due to climate change, threatening to further exacerbate these challenges.[32]

The combination of systemic global interdependencies and intensification of climate change is expected to increase both the scale and speed of climate change impacts.[1,33] Climate change—including increasing temperatures, changing rainfall patterns, and increased frequency of some extreme events—combines with stressors such as conflict, land degradation, biodiversity loss, population growth, and worsening human health to exacerbate food insecurity and potential famine.[34] For example, climate extremes have increased the incidence of multiple concurrent or consecutive breadbasket failures (e.g., poor harvests in major food-producing regions), threatening global food security and leading to cascading effects (e.g., social unrest and higher prices) across multiple geographies that affect US interests.[21,35,36] Since 2018, multiple stressors, including droughts in North America and the Horn of Africa, poor harvests in China and France, the COVID-19 pandemic, and the war in Ukraine have combined to severely test global food security, increasing fertilizer costs and food prices and decreasing food availability.[37]

Given the right conditions, however, interconnectedness can help mitigate risk. For example, food imports can address localized food insecurity and may become more prevalent given climate change impacts.[20,38] Transformative changes in human behavior that lead to "positive tipping points"—including the adoption of new technologies (e.g., energy transition to lower-emissions technologies) or approaches (e.g., regenerative agriculture approaches that increase climate resilience and sustainability of farm and food systems)—can help prevent the worst-case impacts of climate change.[39]

Traditional risk assessment and management approaches tend to focus on single sectors or locations rather than systems and the related complex interdependence of risks.[16,40] However, approaches to decision-making that address adaptation and mitigation early in the process at a systems level, considering the fullest suite of risks, interactions, and optimal response options, are advancing (Ch. 18).[41] Integrating responses vertically (across global, regional, and local levels) and/or horizontally (e.g., multistakeholder partnerships to codesign landscape-scale responses) offers promising insights for addressing these interdependencies across multiple scales and sectors.[42,43,44,45] Scenario planning, "nexus" approaches that address multiple sectors, and other co-development and participatory approaches are being applied to plan in the face of uncertainty, address linkages, and consider the role of response options themselves as risk drivers (Chs. 18, 31).[20,40] More experience is needed in applying and evaluating these emerging approaches to improve policy coherence and coordination across sectors and to better understand sensitivity to system changes and uncertainty.[40,46]

Interconnected Interests and Cascading Impacts



Future impacts to US interests are uncertain given complex system interdependencies and interactions between stressors, capacities, and responses.

Figure 17.1. This figure illustrates how system interdependencies and the interconnected nature of climate change stressors and response choices can lead to uncertain future impacts on US interests (e.g., national security; economics, trade, and investment; and sustainable development). Climate and compounding stressors interact and present different degrees of potential impact to US interests given varying levels of adaptive capacity, sensitivity of interest areas, and the effectiveness of responses in addressing systemic risks and taking advantage of opportunities. The complexity of interacting stressors and interdependent systems can lead to cascading impacts, unintended consequences, and increased uncertainty on future impacts to US Interests. Adapted from Ringsmuth et al. 2022[47] [CC BY 4.0].

Key Message 17.2

Climate Change Exacerbates Risks to National Security

Climate change can contribute to political and social instability and, in some instances, to conflict (*likely*, *high confidence*). It impacts the operations and missions of defense, diplomacy, and development agencies critical to US national security (*very likely*, *high confidence*). The US Government, bilaterally and in collaboration with international partners, is increasingly addressing these implications through a range of diplomatic, development, and defense responses (*very likely*, *high confidence*).

Climate change exacerbates existing security challenges and risks, affecting a wide range of US national security interests.[48,49,50] Climate change impacts and responses can contribute to political and social instability as well as various forms of conflict.[2,49,51,52,53] Security-related concerns can also stem from the impacts of climate change on human lives and livelihoods, food and water security, biodiversity, and ecological and human health, as well as the responses to these impacts.[54,55,56] Inversely, conflict can exacerbate climate-related vulnerabilities, particularly affecting women, children, and overburdened populations.[57] This interplay between climate and conflict can hinder both mitigation and adaptation progress. The risk of destabilization and conflict connected to climate change has implications for US security interests distributed worldwide.

As shown in Table 17.1, the climate risks to US security interests span from local instability to geopolitical tension. In addition to the risks of instability and conflict, compounding dynamics include declining agricultural production and food security;[2] recruitment and influence for extremist or violent groups;[58] and declines in state capacity or legitimacy, including potential corruption, where governments cannot effectively respond to extreme weather events or long-term, chronic climate-connected impacts.[59,60,61]

Table 17.1. Climate Risk Assessment to US Interests

"Risks to US national security interests through 2040 will increase as countries respond to the intensifying physical effects of climate change."[50] For a full explanation, see the National Intelligence Estimate on "Climate Change and International Responses Increasing Challenges to US National Security Through 2040,"[50] from which this table is adapted.

Risk		2021	2030	2040
Climate Effects Impacting Country-Level Instability	Strain on energy and food systems	Low	Medium	High
	Negative health consequences	Low	Medium	Medium
	Internal insecurity and conflict	Low	Low	Medium
	Greater demand for aid and humanitarian relief	Medium	High	High
	Strain on military readiness	None	Low	Medium

Risk		2021	2030	2040
Climate-Exacerbated Geopolitical Flashpoints	Miscalculation over strategic competition in the Arctic leading to conflict	None	Low	Medium
	Cross-border water tension and conflict	Low	Medium	High
	Cross-border migration attributed to climate impacts `	Medium	High	High
	Ungoverned unilateral geoengineering	None	Low	Medium

Risk		2021	2030	2040
Geopolitical Tensions over Climate Responses	Perception of insufficient contributions to reduce emissions	Low	Medium	High
	Carbon dioxide removal not at scale for countries' net-zero pledges	None	Low	Medium
	Developing countries' demands for financing and technology assistance	Medium	High	High
	Petro states resisting clean energy transition away from fossil fuels	Low	Medium	High
	Competition with China over key minerals and clean energy technologies	Low	Medium	High
	Contention over use of economic tools to advance climate interests	None	Low	Medium

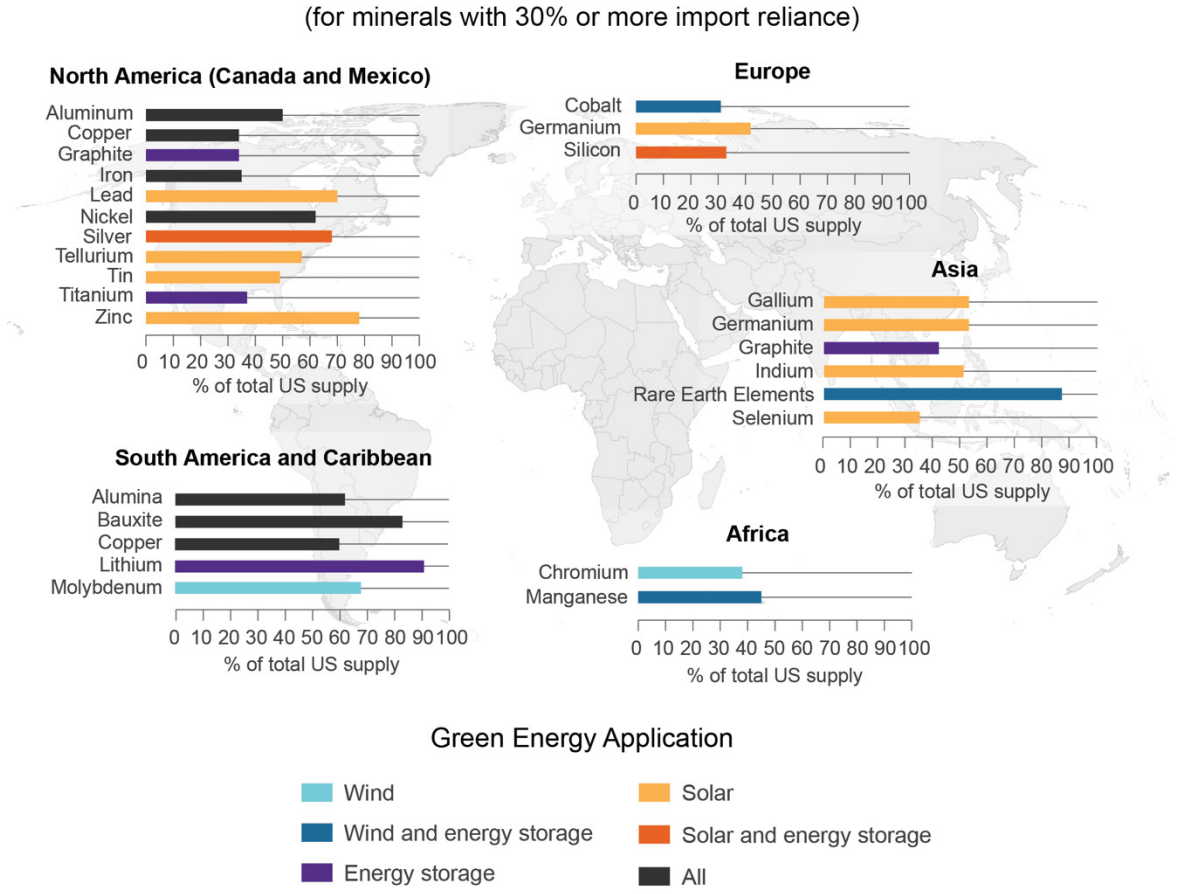
Mobility, both planned and forced, is a common adaptation response to a changing environment, contributing to displacement and migration that primarily occurs within countries and, at times, crosses national boundaries.[31,62,63] Climate change–related mobility, impacting both sending and receiving populations, is expected to increase.[50] Ongoing international engagement continues around climate change and mobility, but limited international governance that provides binding protections for people crossing national borders due to climate change results in varied state and regional responses.[64]

As countries continue to work toward adaptation and mitigation goals, alternative climate interventions are being considered to reduce the warming effect of greenhouse gases and avoid tipping points. One category

of alternative intervention is carbon dioxide removal, technical interventions to remove carbon dioxide from the atmosphere that can have impacts on food systems, biodiversity, and other systems (Chapter 32). Solar radiation modification (SRM) constitutes a variety of approaches to reduce sunlight reaching the lower atmosphere. The potential risks and benefits involving the use of SRM need to be considered relative to the risks and benefits associated with plausible trajectories of ongoing climate change not involving SRM.[65] SRM represents an area of growing interest for national security given the potential for unilateral action from state and non-state actors, evolving understanding of climate and societal impacts, and limited formal or informal mechanisms of engagement.[66,67] Understanding the risks and trade-offs of these alternative climate interventions is a rapidly growing field of study.

Climate change impacts are of particular concern in areas with limited resilience, unequal resource distribution, and/or weak governance structures. Unintended consequences of climate responses can also have important national security implications. For example, mitigation and adaptation efforts can unintentionally exacerbate new or existing conflicts and inequalities affecting marginalized populations.[68,69] Dynamics accompanying an energy transition such as price variability, loss of employment in the fossil fuel sector, and stranded assets for petroleum-producing countries may also contribute to internal protest and reduced support for strengthening international climate change mitigation efforts.[70] International climate change responses are shifting geostrategic and regional interests and priorities. These dynamics include competition for minerals and metals critical for mitigation and renewable energy.[71,72] Figure 17.2 displays the source of these materials, many of which are sourced outside the United States; however, note that China controls much of the market for mining and processing of many of these minerals and metals, leading to heavy dependence on China for resources critical for energy technologies. Moreover, the extraction and processing of these necessary inputs can heighten local ecological, political, and justice tensions.[73] Interests across the Arctic have also come under greater scrutiny as rapid warming opens up natural resource extraction possibilities, new sea transport routes, emergency response expectations in the event of accidents, and increased military activity, particularly by Russia (Chapter 29).

US Net Import Reliance by Region for Minerals Necessary for Renewable Energy Technology



US renewable energy technologies rely on imports of critical minerals from around the world.

Figure 17.2. Many mineral inputs critical for renewable energy technologies are imported to the United States. This figure illustrates the diversity of location, mineral type, application, and scale of import reliance.[74] Adapted from Humphries 2019.[75]

Countries may also leverage climate change mitigation and adaptation policies to gain influence and foster new coalitions. Each country will experience a wide variety of climate-related security concerns that can generate new interests or alter existing interests within bilateral relationships.[50,61] For example, climate change impacts can disrupt global supply chains, such as those for food, energy, and critical minerals.[72] These disruptions affect US national security interests, particularly when occurring in tandem with responses to health, economic, and political crises such as those presented by COVID-19 and the war in Ukraine.

US national security, diplomatic, and development agencies are responding to the national security impacts of climate change and competing with other countries in these engagements.[76,77,78,79] Climate change impacts and responses have implications for defense, diplomacy, and development portfolios, including the climate-altered operational environment, US military and civilian infrastructure in partner countries, and humanitarian response.[49,79,80] Government responses include developing climate mitigation and adaptation plans; adapting operations, assessments, and infrastructure to be more resilient; building adaptive capacity and resilience to reduce future risk; and addressing threats and opportunities with a range of defense, diplomacy, and development approaches.[81,82,83] Within this geopolitical context, countries cooperate and compete and may try to take advantage of climate change impacts to gain influence.[49]

A number of multilateral forums (such as the UN Security Council, UN General Assembly, UN Environment Programme, European Union, North Atlantic Treaty Organization, African Union, and Organization for Security and Co-operation in Europe) recognize the interdependent nature of climate change impacts and their implications for national and regional security and have initiated collaborative responses to address transboundary risks.

Defense, diplomatic, and development institutions face increasing operations and emergency response expectations, often arising in new regions that are geopolitically relevant for US interests, as well as increasing requests for humanitarian support worldwide.[76,84] To ensure continuity of operations around the world, adaptation measures ensuring reliable and functional host country infrastructure and services at risk from climate change are a priority for US federal agencies. With international partners, the US Government is increasingly addressing climate-related risks to US national security through a wide range of responses. Assessing and responding to climate-related national security risks relies on the exchange of quality-assured information across global, regional, national, and local scales (see Box 17.1).

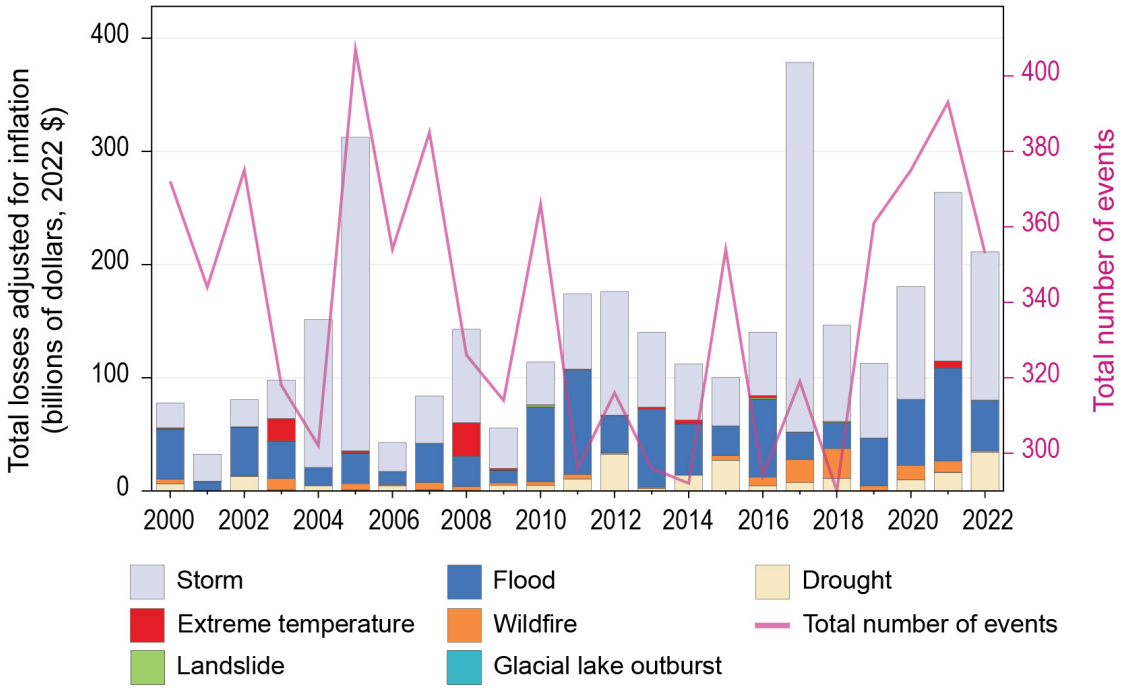
Key Message 17.3

Climate Change Presents Risks and Opportunities for US Economics, Trade, and Investments

The physical impacts of climate change are increasingly affecting global and regional economic growth (*very likely*, *high confidence*). These impacts have important implications for US economic, trade, and investment interests *(likely*, *medium confidence*). Global mitigation and adaptation responses by governments and businesses will likewise impact US economic interests, presenting both risks and potential opportunities for the US economy (*likely*, *medium confidence*). Public- and private-sector institutional, regulatory, financial, and market-based frameworks for climate mitigation and adaptation will influence these risks and opportunities (*likely*, *medium confidence*).

The impacts of climate change on global ecosystems, agriculture, human settlements, infrastructure, health, and migration translate into economic impacts that vary across regions and countries, as well as the extent to which effective adaptation measures are undertaken (Ch. 19).[2,85,86] Losses from climate-influenced disasters are globally widespread and growing, including from a wider range of climate-related events, such as wildfires and floods (Figure 17.3).[87,88,89] Although climate change has played a significant role in these trends, consensus is lacking on the extent to which increased losses are attributable to climate change versus other factors.[90,91]

Climate-Related Disasters and Economic Losses



This figure shows global trends in the number, growing costs, and increasing diversity of types of climate-related natural disasters since 2000.

Figure 17.3. The total global losses associated with climate-related disasters have risen over the last two decades, with growing diversity in the types of climate-related events that lead to disasters (e.g., drought, wildfires, floods) and some annual spikes in storm-related losses. There is little correlation between losses and total number of disasters (suggesting increased losses may derive from increasing severity of disasters, increased value of assets, reporting discrepancies, or a combination of these). Figure credit: DOI, Winrock International, NOAA NCEI, and CISESS NC.

In addition to acute impacts, slow-onset climate impacts such as biodiversity loss and the effects of rising temperatures on health and agriculture in vulnerable regions, as well as nonlinear climate risks (tipping points), will affect economic growth.[92,93] A growing body of literature identifies sea level rise (SLR) as a key driver of economic impacts from climate change, with one study estimating global economy-wide GDP losses as high as 4% by 2100 from SLR-related coastal flooding if no adaptation measures are undertaken.[94]

Climate change impacts beyond US borders expose US economic, trade, and investment interests to risk because these interests are highly integrated in the global economy (Focus on Risks to Supply Chains; Ch. 19). For example, US foreign direct investment overseas and the value of exports and imports reached record levels in 2022.[95,96,97]

Although research relating climate change impacts outside of the US to direct impacts on US trade and investment interests is sparse, analyses suggest several risks to which US overseas investments and trade will be exposed, such as reduced asset values, greater risks of loan default, disincentives for new investments, and trade implications. For example, vulnerable countries face prolonged economic disruption from climate-related disasters, including loss of income and consumption and a higher risk of sovereign debt default.[98,99] Economic shocks in foreign countries are expected to reduce US agricultural exports, production, and farm income (Ch. 11).[100] According to one study, global temperature increases of 3.6°–5.76°F

(2.0°–3.2°C) would reduce midcentury GDP in the US, Canada, and the United Kingdom by 6%–9%, compared to growth without climate change.[101]

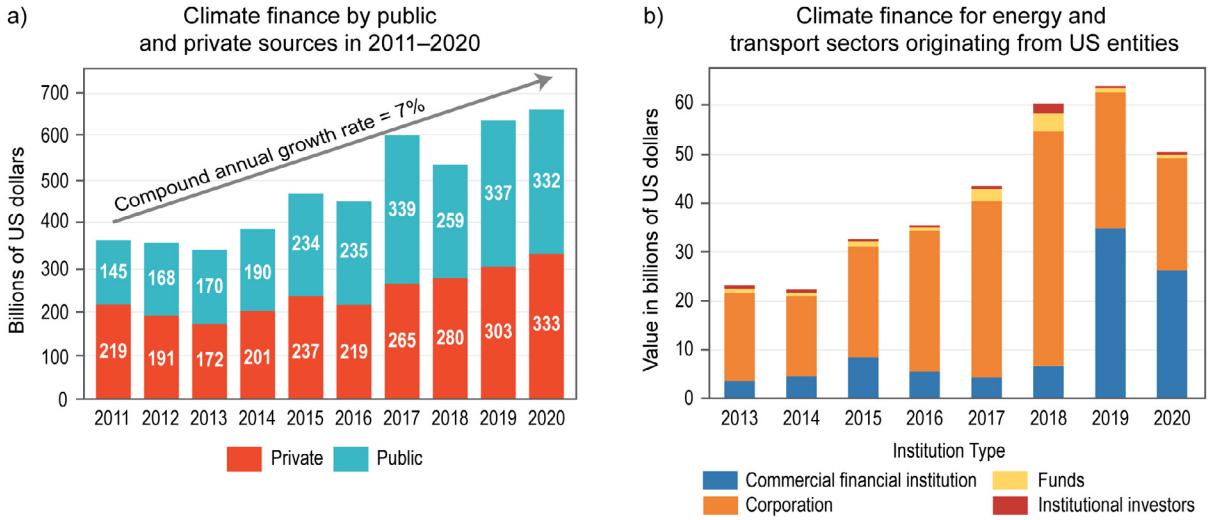
Global climate responses, including policy choices and market responses, present both risks and opportunities for US economic interests as other countries transition toward low-emissions, climate-resilient economies.[86,102] Transition risks include potential job losses, stranded assets, energy price increases, and potential negative impacts on the global financial system.[103] Adaptation responses that restrict development in risk-prone areas could limit options for US investors or leave existing assets exposed.[104]

The global transition, including increased global financing for mitigation and adaptation (Figure 17.4), will also generate innovation, trade, and investment opportunities for US firms (Ch. 19).[105,106,107] Opportunities for innovation and investment include low-carbon energy and carbon capture; transport and infrastructure; adaptation technologies in water, agriculture, health, and other sectors; resilient supply chains; and climate services.[108]

Governments and financial institutions are increasingly using blended finance, green bonds (fixed-income debt instruments that enable investments in climate change mitigation and adaptation), guarantees, and grants to unlock private-sector climate-related investment, including in areas such as land use, reforestation, and adaptation.[109,110] Multistakeholder partnerships are also harnessing market forces to reduce emissions, such as by encouraging deforestation-free commodity supply chains.[111] Workforce development and youth engagement programs are being implemented to prepare economies for the transition to climate-resilient development.[112,113]

Evolving regulatory and market frameworks and financing are important enabling conditions that will influence the effectiveness of global climate responses—including in achieving Paris Agreement climate mitigation and adaptation goals—and their impact on US economic interests.[108,114,115,116] Total global financing for climate mitigation and adaptation (Figure 17.4a) grew steadily from 2011–2020 but slowed in the years just prior to the pandemic and falls short of estimated needs to meet Paris Agreement goals and avoid the worst impacts of climate change.[117] Private-sector contributions increased between 2011 and 2020, although more slowly than public-sector contributions. Adaptation finance grew nearly three times faster than mitigation; however, methodologies for tracking adaptation finance are less developed than mitigation finance and subject to data gaps, particularly from the private sector.[118] While important caveats apply (see Figure 17.4 metadata), US investments in the energy and transport sectors have grown steadily between 2013 and 2020, largely tracking overall global climate finance increases, including in these sectors, albeit more concentrated on domestic US rather than overseas investments (Figure 17.4b).[118]

Climate Finance



Public and private contributions to global climate finance are increasing but not at the pace necessary to avoid the worst impacts of climate change.

Figure 17.4. (**a**) The public and private sectors provided $4.8 trillion in climate finance in total between 2011 and 2020, with the private sector responsible for about half. (**b**) Data on private finance flows originating from the US are most comprehensive for the energy and transport sectors. Figure credits: (a) adapted from Naran et al. 2022[118] [CC BY-NC-SA 4.0]; (b) DOI, Winrock International, and Climate Policy Initiative.

Regulations and economic incentives supporting mitigation and adaptation, carbon markets, climate-related innovation, reduced deforestation, subsidy reform, and climate-related risk disclosure can spur companies, investors, and others to address climate risk (Ch. 19). Public sector policies and frameworks to incentivize greater ambition on mitigation include the 2022 US Inflation Reduction Act (IRA) and the EU's Carbon Border Adjustment Mechanism (CBAM), adopted in May 2023. The CBAM may impose costs for US exporters to Europe and spark retaliatory measures by others, with spillover impacts for US exporters to other regions.[119,120] Although domestically oriented, the IRA may spur investment by US companies in renewable energy and other technologies that could be applied to international markets.

Investors and companies increasingly view climate change mitigation as a business necessity and an opportunity.[108,121,122,123] From November 2020 to November 2021, the number of companies worldwide committing to reducing their carbon footprint to "net zero" through emissions reductions, carbon capture, and emissions offsets by 2050 or sooner had grown from 30 to more than 450, and the value of assets represented multiplied 26 times.[124]

The value of global carbon offset trading quadrupled from 2018 to 2021.[125] The Paris Agreement Article 6 rule book, adopted in 2021, creates global norms for government carbon trading and is expected to inform private transactions.[126,127,128] A maturing carbon offset market is projected to grow 15-fold by 2030 and 100-fold by 2050, presenting opportunities for US firms to meet mitigation goals through overseas investments and the potential to generate resources to support local adaptation measures.[129,130,131,132] There remain concerns that carbon trading could shift burdens onto developing countries, vulnerable communities, and future generations.[133,134]

A growing number of investors and asset owners have committed to evaluate and disclose climate risks. As of September 2022, 3,400 organizations from 95 countries have supported the Task Force on Climate-Related Financial Disclosures, representing nearly all economic sectors.[135] Banks, insurance

companies, and pension regulators are focusing on climate-related risks.[136,137,138] The US Securities and Exchange Commission has proposed mandatory climate financial risk disclosure, paralleling similar actions by the United Kingdom and others.[139,140]

Despite growing corporate interest in addressing climate change, implementation lags behind commitments to climate risk disclosure and net-zero goals. Pressure is growing to convert these commitments into credible measurable actions, including through science-based targets.[113,141,142,143,144] Small- and medium-sized enterprises may face challenges navigating complex reporting standards, which could impact their competitiveness and access to financing.[145] Increased climate risk disclosure may increase costs and discourage US investment in vulnerable areas.[146]

Despite historic challenges, increased awareness of risks and market opportunities has begun to generate interest in private investment in adaptation. Private-sector adaptation investment has begun to be tracked alongside public climate adaptation finance, although less than $500 million was identified in 2021.[117] Institutional investors have begun to develop frameworks for investing in climate adaptation and resilience opportunities.[147] The Adaptation Solutions Taxonomy, peer-reviewed and released in 2020, identifies companies supporting adaptation and climate resilience solutions.[148] The first private investment fund secured $185 million for climate resilience and adaptation technologies in 2022.[149]

While government regulations, expenditures, and market-driven climate responses are key to creating enabling environments for climate responses, they can also increase corruption risks, which in turn can undermine business efficiency, frustrate the effectiveness of climate responses, and exacerbate insecurity or poor governance.[59,60] Thus, enabling environments to ensure transparent, accountable, and participatory climate responses may impact the balance of risks and opportunities for US businesses and economic interests.[150,151,152]

Key Message 17.4

Climate Change Undermines Sustainable Development

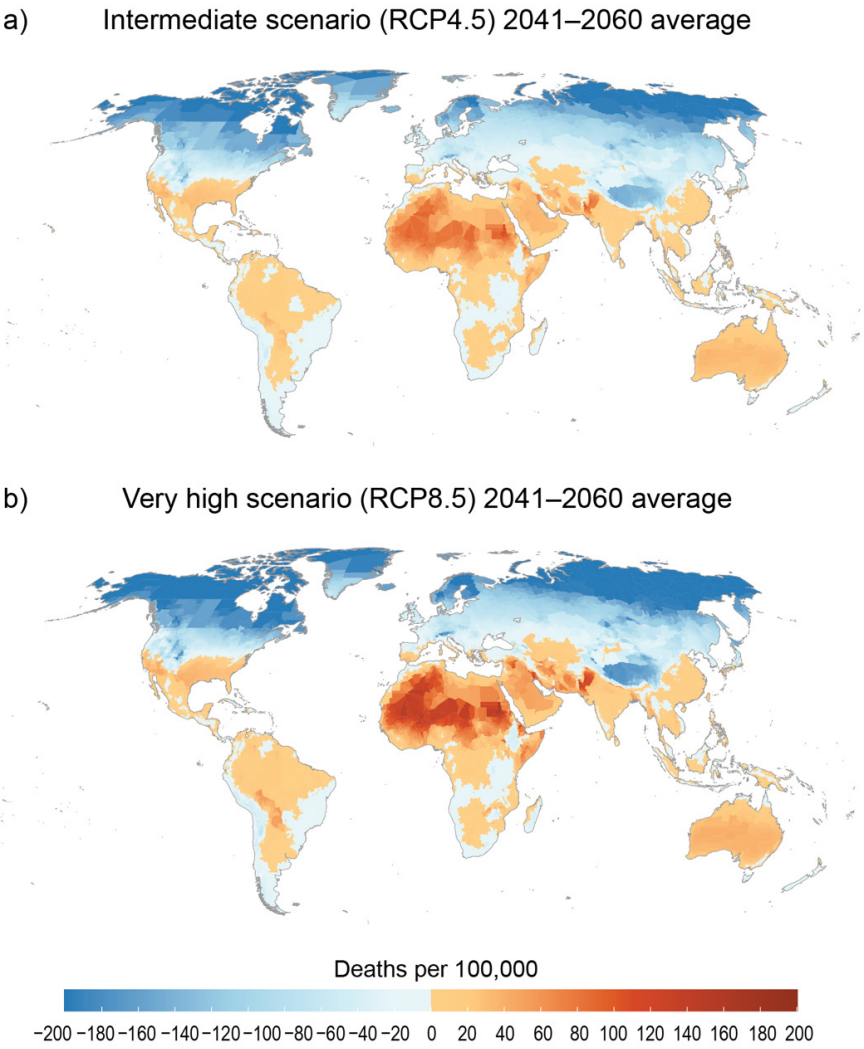
Climate change undermines the world's ability to develop sustainably, reverses development gains, and exacerbates inequities (*very likely*, *high confidence*). Climate finance is increasing, but global flows continue to fall short of needs (*likely*, *high confidence*). Accelerated deployment of adaptation and mitigation action at scale can yield substantial benefits for sustainable development (*likely*, *medium confidence*). Climate action is most effective when co-developed and grounded in equity, local ownership, and inclusive governance (*likely*, *medium confidence*).

The impacts of climate change are globally pervasive, touching all aspects of human, built, and natural systems, including food security, poverty, health, water, infrastructure, and education, among others. Climate change is a risk multiplier in the face of existing development challenges, such as a rapidly growing population base; increased migration, particularly to urban centers, and displacement; increased food insecurity; and rising energy demands. These development challenges are also hampered by reductions in the capacity of natural resources and landscapes to buffer against increased risks, an inability of lifeline services to keep pace with needs, limited economic diversification, low educational levels, and weak institutions to manage these changes.[153] In conjunction with these and other factors (Figures 17.1, 17.2), climate change undermines sustainable development, reversing the significant development gains made in recent decades.[154,155,156,157] These challenges highlight the need to take into account the impacts

of climate in development trajectories in order to inform mitigation and adaptation response to achieve sustainable development.[158,159,160]

Globally, an estimated 26 million people are falling into poverty every year due to extreme weather events such as floods and droughts, and projections point to millions more that could be pushed into poverty by midcentury due to climate change.[153,161] Climate change impacts fall disproportionately on low-income countries and on marginalized and underrepresented populations, which have fewer resources to adapt. Figure 17.5 shows the differential mortality risks from climate change around the world, which results in unequal distribution of risk between and within countries. Limited resources, response capacities, and geophysical and socioeconomic constraints can reduce the feasibility of adaptation.[162,163,164,165] In some contexts, impacts will be beyond the ability of communities to adapt (Ch. 31).[2] This raises equity concerns, particularly given the relatively small greenhouse gas contributions of many low-income populations.[166,167]

Impact of Climate Change on Mortality Rates in 2050



Climate change will exacerbate global inequalities in mortality rates.

Figure 17.5. A warmer world will interact with existing differential capacities, shifting mortality patterns. Even when accounting for future adaptation and rising incomes, mortality will significantly increase in the Global South. The maps show projected changes in mortality due to climate change in 2050 (averaged over 2041–2060) for (**a**) an intermediate scenario (RCP4.5) and (**b**) a very high scenario (RCP8.5). Adapted with permission from Carleton et al. 2020.[168]

Despite growing climate financing, global finance flows continue to fall short of mitigation and adaptation goals and needs.[2,117] To avoid the most dangerous impacts of climate change, annual international climate finance flows in support of adaptation and mitigation efforts would need to increase by 3 to 6 times from current levels by 2030.[2] Even if mitigation finance goals were met, adaptation finance and the resulting percentage of climate finance toward adaptation would need to increase as well.[169] Adaptation costs for developing countries alone are projected to be $140–$300 billion annually by 2030 and $280–$500 billion by 2050 (dollar year not reported), and some estimates go further to propose a doubling or tripling every few years.[107] To date, most adaptation investments have been fragmented, project-based, small-scale, incremental, sector-specific, and more focused on near-term risks and planning.[170] Achieving mitigation and adaptation goals requires alignment of domestic, international, public, and private investment, practices, and business models.[117]

The increasing debt burden many countries incur to manage climate risks and restore economies and livelihoods after extreme events represents a growing obstacle to sustainable development.[153,171] Although large disasters make headlines, globally the cumulative losses from small-scale recurring disasters account for a larger portion of economic losses and erode community resilience.[2] Proactive investments can help safeguard against budget restructuring or reallocations as extreme events become more frequent. For example, investments in early warning systems, flood inundation models, and insurance schemes could have offered protection and limited the long-term effect of the recent floods in Pakistan, where development funds were diverted to disaster response.

Adaptation investments can be affordable, with benefits that far exceed costs not just in terms of financial costs and benefits but also in reduced humanitarian spending, avoided asset losses, and lives and livelihoods saved.[2] The net benefits of investing in mitigation and adaptation include reduced future losses, positive economic outcomes, and social and environmental benefits. Mitigation benefits are expected to exceed costs, even without comprehensive accounting for avoided losses, reduced adaptation needs, and co-benefits, and higher near-term investments are projected to lead to long-term economic gains.[2] The benefits of investing in adaptation across a range of sectors are significant, spanning from $2–$13 for each $1 invested, with some of the higher ranges being associated with investments in infrastructure resilience, early warning and response, and disaster risk management.[172,173,174] Conversely, estimates of the costs of inaction range from a 7% to 14% reduction in global GDP.[101,175]

There is evidence of effective mitigation and adaptation options that are feasible to achieve at scale in specific contexts.[2] Accelerated response to climate change can shift development pathways toward increased sustainable development outcomes despite climate change trajectories. Climate-resilient development efforts are enabled by responses that span policy, diplomacy, public and private investment, and the development and humanitarian assistance domains.[2,176,177,178,179] Increasingly affordable and accessible low-emissions technologies support shifting away from fossil fuels to limit warming.[2] Policy interventions at multiple levels, especially those involving ambitious near-term mitigation targets from current and projected major emitters, can minimize potential for overshooting 1.5°C (2.7°F) warming.[2] Adaptation efforts can reduce disruptions due to shocks and stressors and help countries and people accelerate responsive solutions, aligned with local needs and opportunities, leading to sustainable outcomes, especially for vulnerable populations.[2,180] Internationally, increased coherence and coordination among humanitarian, peace-building, resilience-building, and development can help address convergent risks and opportunities.[181] Participation in international and transboundary climate efforts is shown to result in national and subnational government and civil society action.[169]

Integrated approaches to mitigation and adaptation can further amplify co-benefits of actions.[182] For example, mangrove conservation and restoration, one of many nature-based solutions with mitigation and adaptation outcomes, can minimize the risk of coastal flooding, reduce greenhouse gas emissions, sequester

carbon, and contribute to broader sustainable development benefits related to food security and nutrition, economic prosperity, marine and coastal protection, and natural habitat and biodiversity.[4] Response options also have trade-offs with each other and with various sustainable development goals due to the complex interconnectivity of climate and non-climate risk (Ch. 31). Increased attention to adverse impacts of responses and development pathways can help avoid lock-in of emissions trajectories, maladaptation, and exacerbated inequalities.[2] Further, global momentum and evidence are growing on approaches to accelerate transformative climate actions that embed systems thinking and innovation to facilitate more resilient development pathways.[183,184,185]

Inclusive governance favoring locally led, collaboratively developed responses can strengthen the potential for enabling effective and equitable climate-resilient development outcomes at scale.[26,185] Meaningful engagement of affected groups (including those historically underrepresented and/or marginalized) and the co-development of information and solutions build capacity and increase support for long-term sustainable and equitable response outcomes (KMs 31.1, 32.2).[186,187] Decision-relevant information, and the capacity to use it in novel ways, underpins effective responses.[188,189,190] This information may be global or local and derived from diverse knowledge sources, including the scientific community as well as Traditional Knowledge. Governance and decision-making processes that integrate climate into substantial development efforts and account for the above factors can minimize trade-offs and adverse impacts and result in climate action that advances US interests in broader sustainable development outcomes.[185]

Traceable Accounts

Process Description

This chapter focuses on the implications of international impacts of climate change on US interests. It does not address or summarize all international impacts of climate change. The topics in the chapter—interdependent climate-related risks; national security; economics, investment, and trade; sustainable development; and climate services—were selected because they represent critical interests that are being affected by climate impacts outside of US borders. Climate effects to these interest areas are context specific and are pervasive across the world. The chapter is limited in terms of providing specific detail due primarily to space constraints and limited literature that specifically addresses climate impacts to US interests.

The authors agree that this points to the lack of a sufficiently timely, policy-oriented, and geographically detailed US Government scientific assessment of climate change outside the US. In addition, current literature does not adequately address or provide evidence on the wide range of response options that could be taken to mitigate impacts. Therefore, US national security and international policymakers and analysts must rely on IPCC assessments, existing academic literature, in-house analysis, or ad hoc contracted studies, which are suboptimal or potentially inconsistent.

Chapter leadership sought an author team that could bring diverse experience, expertise, and perspectives. Care was taken to ensure that the team included both early-career and senior professionals from across government, academia, and the private sector who came from varying geographic areas and personal backgrounds. The authors were selected from the list of individuals who responded to the Federal Register Notice or otherwise directly contacted the US Global Change Research Program (USGCRP) to volunteer. Technical contributors were onboarded to conduct an extensive literature review to further identify any dissensions and help reconcile different inputs. Technical contributors also supported design and development of selected figures. The writing team engaged in conference calls starting in September 2021, and calls continued on a regular basis to discuss content, writing, and technical and logistical issues related to the chapter. The NOAA Technical Support Unit staff joined some of these regular conference calls. Subsets of chapter authors also held conference calls on literature, content, and writing on different sections of the chapter.

Public feedback was sought via Federal Register Notices and a public engagement workshop. During the workshop, the USGCRP and chapter authors shared information about the progress to date of the chapter and sought input from stakeholders to help inform further development of the chapter, as well as to raise general awareness of the process and timeline for the Fifth National Climate Assessment (NCA5).

Key Message 17.1

Interdependent, Systemic Climate-Related Risks Increasingly Affect US Interests

Description of Evidence Base

The literature base on climate change and systemic, interdependent risk has grown significantly since the publication of the Fourth National Climate Assessment (NCA4) in 2018, which looked into transboundary climate risk—that is, how climate impacts in neighboring countries affect US interests. However, the literature on global systemic risks cannot yet be considered expansive; it has evolved from a focus on the

financial sector and has more recently increased—not as a result of climate shocks but rather due to recent supply chain disruptions and the observed ripple effects of COVID-19, which put that interconnectivity into stark relief. According to Li et al. (2021)[19] and Simpson (2021),[20] the existing literature highlights the importance of climate change as a driver of systemic risk, but there is a gap in understanding in terms of the interactions and dynamics that generate risk, the methods to support risk assessment, and the design of adaptation and mitigation responses to address complex risk. There is a lack of evidence surrounding the effectiveness of emerging systems- and scenarios-based approaches that are being designed and implemented to address complex, interdependent risk.[40,46]

Major Uncertainties and Research Gaps

The literature is evolving from predominantly sector- (e.g., water security, food security) or domain-based (e.g., urban areas) risk assessment toward consideration of complex, interdependent systems that can result in compounding and cascading climate impacts.

There is little available literature that focuses on broad and cascading impacts of interconnected/interdependent climate risks in relation to compounding and cascading effects on multiple US interests. Nor is there a literature base that assesses the performance of approaches and measures to address systemic, interdependent risk.

Description of Confidence and Likelihood

There is *high confidence* and it is *likely* that in a globally connected world, climate change impacts on US interests are multifaceted, interconnected, and frequently exacerbated by social unrest and environmental degradation. These interconnections and their ripple effects are well documented.

There is *high confidence* and it is *likely* that the scale and speed of climate-related impacts to US interests are expected to increase, due in part to underlying interdependencies and to the projected intensification of climate change. It is unequivocal that climate change is intensifying and that it will result in increased impacts across systems and value chains.

There is *high confidence* and it is *likely* that emerging systems- and scenarios-based approaches to integrative planning are being applied to account for interdependencies and competing priorities. Although these approaches have been developed and are being applied to identify risks and responses, the literature surrounding their effectiveness is less advanced.

Key Message 17.2

Climate Change Exacerbates Risks to National Security

Description of Evidence Base

The literature base on climate change and national security has grown significantly since NCA4, as well as in the approximately 15 years since it became a more prominent focus for scholars and practitioners.[48,53] Given the significant diversity of topics and regions considered for links between climate change and national security, the literature is evolving and cannot yet be considered expansive. Some research questions for which the literature was limited and contested during the NCA4 review period have since seen significant additions and greater agreement among findings, including collaborative research efforts among large groups of scholars. An example of this convergence of findings in recent years involves questions around causal links between select climate impacts and the onset of conflict.[52] Literature on other research questions, such as causal links between climate responses and conflict, is less advanced and more deductive,

often based on historic responses in related issue areas. The number and diversity of US government responses to climate change and national security actions have expanded since the NCA4 review.[49,50]

Major Uncertainties and Research Gaps

Given the diversity of potential research topics connected to climate change and national security, a number of issue areas and geographies have limited literature using diverse methods. In some cases, data remain limited in scales and locations, which constrains the types of methods that can be utilized. In other instances, the institutional responses to climate change that may have national security implications remain in early stages and therefore do not present an evidence base that could generate research findings with the highest levels of confidence.

Description of Confidence and Likelihood

There is *high confidence* and it is *likely* that climate change can be a contributing factor to political and social instability and in some instances conflict. There is *high confidence* and it is *very likely* that climate change increasingly impacts the operations and missions of defense, diplomacy, and development agencies and departments critical to US national security. There is *high confidence* and it is *very likely* that defense, diplomacy, and development agencies and departments are increasingly addressing climate impacts and responses across the government. These confidence levels are based on an in-depth review of a robust body of literature drawn from numerous disciplines, as well as a growing set of US Government and international policies, programs, and assessments.

Key Message 17.3

Climate Change Presents Risks and Opportunities for US Economics, Trade, and Investments

Description of Evidence Base

There is significant research on global and regional impacts of acute and chronic climate-mediated risks.[2] There is an emerging body of literature that analyzes economic impacts of these risks on global and regional economies.[85,86] However, studies that draw conclusions regarding macro-level economic impacts of climate change (e.g., Swiss Re 2021[101]) require assumptions regarding the cost of uncertainty that would benefit from peer review and more analysis. The most granular data on the costs of physical climate impacts pertain to acute risks, such as climate-mediated disasters, rather than chronic risks. However, there is debate among scholars on the degree to which the economic effects of acute events are attributable to climate change.[90,91]

Figure 17.3 reflects data reported to EM-DAT, the International Disaster Database on disaster-related events, types, and costs.[191] The categorization of data within this database is dependent on how events are reported, and there may be some discrepancies in how specific events and associated losses are characterized by reporters. For example, EM-DAT captures events and quantifies losses for storm events (including tropical, extratropical, and convective storms) as well as floods (including coastal, riverine, flash, and ice-jam floods). However, EM-DAT does not provide guidance to data reporters for distinguishing flood events from storm events; as a result, damages from floods caused by storm events could potentially be reflected under either "storms" or "floods." However, the purpose of the figure is to show overall trends in event types and damages; the potential for discrepancies in how these events and associated damages are reported in the database is not material to the overall intent of the figure.

A relatively sparse but growing body of literature analyzes economic effects of climate change on sectors or topics in which US economic interests are highly embedded, such as sovereign lending,[98,99]

agriculture,[100,192,193,194] and migration.[195] These studies offer insights from which expected economic impacts on US economics, trade, and investment may be inferred; however, they generally fall short of attempting to quantify isolated impacts to US economic interests.

A growing body of literature from think tanks, consultants, multistakeholder organizations, and institutional sources provides empirical evidence of trends and practices regarding economic risks and opportunities and participation of private-sector interests in climate responses. The literature available in peer-reviewed scientific journals is less extensive than reports and studies available from non-peer-reviewed sources but is growing. Recent literature addresses the impact of corruption on climate responses. However, the most comprehensive and authoritative assessment of corruption risks posed by climate responses derives from a 2011 study.[152]

Major Uncertainties and Research Gaps

Literature estimating the global and regional economic impacts of physical climate risks, as well as of mitigation and adaptation response choices, is evolving. In addition to more granular analysis of these impacts across different risk categories, gaps in the literature include analysis of how economic impacts outside the US spill over into impacts on US economic, trade, and investment interests. Greater exploration of how policy, regulatory, market, and financial enabling environments mitigate or exacerbate economic, trade, and finance impacts—both at the global and regional levels as well as for US interests—would be valuable. The interrelationship of corruption and climate responses is a topic of emerging relevance that would benefit from updated research and analysis.

Description of Confidence and Likelihood

There is *high confidence* and it is *very likely* that the physical impacts of climate change are increasingly affecting economic growth at global and regional levels outside of the United States.

There is less authoritative analysis of how these global and regional economic impacts translate into impacts on US economic, trade, and investment interests. Studies of specific areas of economic impact in which US economic interests are highly embedded suggest *likely* implications for US interests, which can be inferred with *medium confidence*.

Similarly, while it is clear that responses by governments and the private sector to climate change will affect the economic impacts of climate change globally and in specific regions and that these responses are expected to translate into both risks and opportunities for US economic, trade, and investment interests, there is a lack of precise analysis attempting to quantify these effects. Consequently, these impacts are assessed as *likely* and with *medium confidence*.

An important mediator of these impacts is the quality and effectiveness of policy, regulatory, market, and financial frameworks that governments and private institutions develop to enable climate change mitigation and adaptation responses. The impact of these enabling environments on US economic, trade, and investment interests is assessed as *likely* and with *medium confidence*.

These confidence levels are based on empirical observation of trends and developments, supplemented with scholarly analysis and significant data relevant to business practice and sentiment reflected in the copious trade literature.

Key Message 17.4

Climate Change Undermines Sustainable Development

Description of Evidence Base

The literature base on climate change, sustainable development, and disaster risk reduction and recovery has grown since NCA4. The literature base is expansive given the diversity of topics, and it is further evolving. Some research questions where the literature was limited and contested during the NCA4 review period have seen significant additions and greater agreement among findings. An example of this convergence can be found in the improved understanding of the importance of interconnectivity of climate and non-climatic impacts on populations and potential effective response options.[185] There has been an increase in literature on the social and economic impacts of climate change and on the implications for poverty and exacerbating inequality.[153,161] Likewise, increasing evidence not only points to the growing need for climate finance and aligning investments for both mitigation and adaptation but also recognizes that while climate finance is increasing, it is not matching or keeping pace with this need. The evidence base on response options has greatly expanded, and the authors have focused on emerging trends and cross-cutting efforts instead of attempting to represent the vast literature on specific response options within various sectors.

Major Uncertainties and Research Gaps

Given the diversity of potential research topics connected to climate change, sustainable development, and disaster risk reduction and recovery, there is not consistent depth of literature across research topics, geographies, levels (from local to international), and sectors. In some cases, data remain limited in scales and locations, which constrains the types of methods that can be utilized. In other instances, the nature, extent, and effectiveness of responses relative to this section remain in early stages and therefore do not present an evidence base that could generate research findings with the highest levels of confidence. Additionally, the evidence base on the costs and benefits of implementing proactive adaptation strategies is ample but fragmented and very context dependent.

Description of Confidence and Likelihood

There is *high confidence* and it is *very likely* that climate change undermines the world's ability to develop sustainably, reverses development gains, and exacerbates inequities. Climate change is threatening achievability of the 2030 Sustainable Development Goals, and impacts are *very likely* falling disproportionately on poor, marginalized, and underrepresented populations, and on developing countries in particular, raising equity concerns given that these individuals and countries contributed least to climate change.

There is *high confidence* and it is *likely* that climate finance is increasing, but global flows continue to fall short of needs. There is a significant literature base to support the statements that climate finance is growing but not keeping pace with current needs and that proactive investment is more cost effective than reactive investments.

There is less analysis and evidence regarding the benefits of large-scale mitigation and adaptation action at scale, leading to *medium confidence* and an assessment of *likely* that accelerated deployment of adaptation and mitigation action at scale can yield substantial benefits for sustainable development.

There is *medium confidence* and it is *likely* that climate action is most effective when co-developed and grounded in equity, local ownership, and inclusive governance.

References

1. IPCC, 2021: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou, Eds. Cambridge University Press, Cambridge, UK and New York, NY, USA, 2391 pp. https://doi.org/10.1017/9781009157896

2. IPCC, 2022: Climate Change 2022: *Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Pörtner, H.-O., D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama, Eds. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp. https://doi.org/10.1017/9781009325844

3. IPCC, 2018: *Global Warming of 1.5°C. an IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts To Eradicate Poverty*. Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, Eds. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157940

4. GCA, 2019: Adapt Now: A Global Call for Leadership on Climate Resilience. Global Commission on Adaptation. https://gca.org/wp-content/uploads/2019/09/GlobalCommission_Report_FINAL.pdf

5. Pulwarty, R., L. Hiebert-Girardet, R.M. Speck, E. Allis, C. Honoré, and J. Stander, 2022: Risk to resilience: Climate change, disasters and the WMO-UNDRR Centre of Excellence. *Bulletin n°*, **71** (1). https://public.wmo.int/en/resources/bulletin/risk-resilience-climate-change-disasters-and-wmo-undrr-centre-of-excellence

6. UNDRR, 2020: *The Human Cost of Disasters: An Overview of the Last 20 Years* (2000–2019). United Nations Office for Disaster Risk Reduction. https://www.undrr.org/publication/human-cost-disasters-overview-last-20-years-2000-2019

7. GAO, 2015: Climate Information: A National System Could Help Federal, State, Local, and Private Sector Decision Makers Use Climate Information. GAO-16-37. U.S. Government Accountability Office, Washington, DC. https://www.gao.gov/assets/gao-16-37.pdf

8. Hewitt, C.D., E. Allis, S.J. Mason, M. Muth, R. Pulwarty, J. Shumake-Guillemot, A. Bucher, M. Brunet, A.M. Fischer, A.M. Hama, R.K. Kolli, F. Lucio, O. Ndiaye, and B. Tapia, 2020: Making society climate resilient: International progress under the global framework for climate services. *Bulletin of the American Meteorological Society*, **101** (2), E237–E252. https://doi.org/10.1175/bams-d-18-0211.1

9. OSTP, 2023: A Federal Framework and Action Plan for Climate Services. White House Office of Science and Technology Policy. https://www.whitehouse.gov/wp-content/uploads/2023/03/ftac_report_03222023_508.pdf

10. IPCC, 2012: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley, Eds. Cambridge University Press, Cambridge, UK and New York, NY, USA, 582 pp. https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/

11. IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Pachauri, R.K. and L.A. Meyer, Eds. Intergovernmental Panel on Climate Change, Geneva, Switzerland, 151 pp. http://ipcc.ch/report/ar5/syr/

12. WMO, 2014: Climate Services for Supporting Climate Change Adaptation. WMO-No. 1170. World Meteorological Organization, Geneva, Switzerland. https://library.wmo.int/doc_num.php?explnum_id=7936

13. Dinku, T., 2019: Ch. 7. Challenges with availability and quality of climate data in Africa. In: *Extreme Hydrology and Climate Variability*. Melesse, A.M., W. Abtew, and G. Senay, Eds. Elsevier, 71–80. https://doi.org/10.1016/b978-0-12-815998-9.00007-5

14. Grossi, A. and T. Dinku, 2022: Enhancing national climate services: How systems thinking can accelerate locally led adaptation. *One Earth*, **5** (1), 74–83. https://doi.org/10.1016/j.oneear.2021.12.007

15. Pulwarty, R.S. and M.V.K. Sivakumar, 2014: Information systems in a changing climate: Early warnings and drought risk management. *Weather and Climate Extremes*, **3**, 14–21. https://doi.org/10.1016/j.wace.2014.03.005

16. UNDRR, 2021: *GAR Special Report on Drought 2021*. United Nations Office for Disaster Risk Reduction, Geneva, Switzerland. https://droughtmanagement.info/literature/UN-GAR_Specia_Report_on_Drought_2021.pdf

17. Vogel, C., A. Steynor, and A. Manyuchi, 2019: Climate services in Africa: Re-imagining an inclusive, robust and sustainable service. *Climate Services*, **15**, 100107. https://doi.org/10.1016/j.cliser.2019.100107

18. WMO, 2020: 2020 State of Climate Services: Risk Information and Early Warning Systems. WMO-No. 1252. World Meteorological Organization, Geneva, Switzerland. https://public.wmo.int/en/resources/library/2020-state-of-climate-services-report

19. Li, H.-M., X.-C. Wang, X.-F. Zhao, and Y. Qi, 2021: Understanding systemic risk induced by climate change. *Advances in Climate Change Research*, **12** (3), 384–394. https://doi.org/10.1016/j.accre.2021.05.006

20. Simpson, N.P., K.J. Mach, A. Constable, J. Hess, R. Hogarth, M. Howden, J. Lawrence, R.J. Lempert, V. Muccione, B. Mackey, M.G. New, B. O'Neill, F.E. Otto, H.-O. Pörtner, A. Reisinger, D. Roberts, D.N. Schmidt, S. Seneviratne, and C.H. Trisos, 2021: A framework for complex climate change risk assessment. *One Earth*, **4** (4), 489–501. https://doi.org/10.1016/j.oneear.2021.03.005

21. Gaupp, F., J. Hall, S. Hochrainer-Stigler, and S. Dadson, 2020: Changing risks of simultaneous global breadbasket failure. *Nature Climate Change*, **10** (1), 54–57. https://doi.org/10.1038/s41558-019-0600-z

22. UNDRR, 2019: Ch. 2. Systemic risks, the Sendai Framework and the 2030 agenda. In: *Global Assessment Report on Disaster Risk Reduction*. United Nations Office for Disaster Risk Reduction, Geneva, Switzerland, 35–73. https://gar.undrr.org/report-2019.html

23. Armstrong McKay, D.I., A. Staal, J.F. Abrams, R. Winkelmann, B. Sakschewski, S. Loriani, I. Fetzer, S.E. Cornell, J. Rockström, and T.M. Lenton, 2022: Exceeding 1.5°C global warming could trigger multiple climate tipping points. *Science*, **377** (6611), 7950. https://doi.org/10.1126/science.abn7950

24. UNDRR, 2022: *Global Assessment Report on Disaster Risk Reduction 2022: Our World at Risk: Transforming Governance for a Resilient Future*. United Nations Office for Disaster Risk Reduction, Geneva, Switzerland. https://www.undrr.org/gar/gar2022-our-world-risk-gar

25. Hurlbert, M., J. Krishnaswamy, E. Davin, F.X. Johnson, C.F. Mena, J. Morton, S. Myeong, D. Viner, K. Warner, A. Wreford, S. Zakieldeen, and Z. Zommers, 2019: Ch. 7. Risk management and decision making in relation to sustainable development. 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*. Shukla, P.R., J. Skea, E.C. Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J.P. Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, and J. Malley, Eds. Cambridge University Press, Cambridge, UK and New York, NY, USA, 673–800. https://doi.org/10.1017/9781009157988.009

26. UN Inter-agency Task Force on Financing for Development, 2021: Financing for Sustainable Development Report 2021. United Nations, New York. https://www.un.org/sustainabledevelopment/wp-content/uploads/2022/03/2021-Report.pdf

27. Cheatham, A. and D. Roy, 2022: Central America's Turbulent Northern Triangle. Council on Foreign Relations. https://www.cfr.org/backgrounder/central-americas-turbulent-northern-triangle

28. Shultz, J.M., R.C. Berg, J.P. Kossin, F. Burkle Jr, A. Maggioni, V.A. Pinilla Escobar, M.N. Castillo, Z. Espinel, and S. Galea, 2021: Convergence of climate-driven hurricanes and COVID-19: The impact of 2020 hurricanes Eta and Iota on Nicaragua. *The Journal of Climate Change and Health*, **3**, 100019. https://doi.org/10.1016/j.joclim.2021.100019

29. Sigelmann, L., 2019: The Hidden Driver: Climate Change and Migration in Central America's Northern Triangle. American Security Project, 23 pp. http://www.jstor.org/stable/resrep19824

30. Spencer, N. and M.-A. Urquhart, 2018: Hurricane strikes and migration: Evidence from storms in Central America and the Caribbean. *Weather, Climate, and Society*, **10** (3), 569–577. https://doi.org/10.1175/wcas-d-17-0057.1

31. The White House, 2021: Report on the Impact Of Climate Change on Migration. The White House, Washington, DC, 37 pp. https://www.whitehouse.gov/wp-content/uploads/2021/10/report-on-the-impact-of-climate-change-on-migration.pdf

32. Castellanos, E., M.F. Lemos, L. Astigarraga, N. Chacón, N. Cuvi, C. Huggel, L. Miranda, M.M. Vale, J.P. Ometto, P.L. Peri, J.C. Postigo, L. Ramajo, L. Roco, and M. Rusticucci, 2022: Ch. 12. Central and South America. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Pörtner, H.-O., D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama, Eds. Cambridge University Press, Cambridge, UK and New York, NY, 1689–1816. https://doi.org/10.1017/9781009325844.014

33. Mann, M.E., S. Rahmstorf, K. Kornhuber, B.A. Steinman, S.K. Miller, S. Petri, and D. Coumou, 2018: Projected changes in persistent extreme summer weather events: The role of quasi-resonant amplification. *Science Advances*, **4** (10), 3272. https://doi.org/10.1126/sciadv.aat3272

34. Mbow, C., C. Rosenzweig, L.G. Barioni, T.G. Benton, M. Herrero, M. Krishnapillai, E. Liwenga, P. Pradhan, M.G. Rivera-Ferre, T. Sapkota, F.N. Tubiello, and Y. Xu, 2019: Ch. 5. 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*. Shukla, P.R., J. Skea, E.C. Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, and J. Malley, Eds. Cambridge University Press, Cambridge, UK and New York, NY, USA, 437–550. https://doi.org/10.1017/9781009157988.007

35. Brown, M.E., J.M. Antle, P. Backlund, E.R. Carr, W.E. Easterling, M.K. Walsh, C. Ammann, W. Attavanich, C.B. Barrett, M.F. Bellemare, V. Dancheck, C. Funk, K. Grace, J.S.I. Ingram, H. Jiang, H. Maletta, T. Mata, A. Murray, M. Ngugi, D. Ojima, B. O'Neill, and C. Tebaldi, 2015: Climate Change, Global Food Security, and the U.S. Food System. U.S. Department of Agriculture, 146 pp. https://doi.org/10.7930/j0862dc7

36. Hallegatte, S., M. Fay, and E.B. Barbier, 2018: Poverty and climate change: Introduction. *Environment and Development Economics*, **23** (3), 217–233. https://doi.org/10.1017/s1355770x18000141

37. Osendarp, S., G. Verburg, Z. Bhutta, R.E. Black, S.d. Pee, C. Fabrizio, D. Headey, R. Heidkamp, D. Laborde, and M.T. Ruel, 2022: Act now before Ukraine war plunges millions into malnutrition. *Nature*, **604**, 620–624. https://doi.org/10.1038/d41586-022-01076-5

38. Smith, V.H. and J.W. Glauber, 2020: Trade, policy, and food security. *Agricultural Economics*, **51** (1), 159–171. https://doi.org/10.1111/agec.12547

39. Lenton, T.M., S. Benson, T. Smith, T. Ewer, V. Lanel, E. Petykowski, T.W.R. Powell, J.F. Abrams, F. Blomsma, and S. Sharpe, 2022: Operationalising positive tipping points towards global sustainability. *Global Sustainability*, **5**, e1. https://doi.org/10.1017/sus.2021.30

40. Liu, J., H. Mooney, V. Hull, S.J. Davis, J. Gaskell, T. Hertel, J. Lubchenco, K.C. Seto, P. Gleick, C. Kremen, and S. Li, 2015: Sustainability. Systems integration for global sustainability. *Science*, **347** (6225), 1258832. https://doi.org/10.1126/science.1258832

41. Hill, A., D. Mason, J.R. Potter, M. Hellmuth, B. Ayyub, and J.W. Baker, 2019: Ready for Tomorrow: Seven Strategies for Climate-Resilient Infrastructure. Hoover Institution. https://www.hoover.org/research/ready-tomorrow-seven-strategies-climate-resilient-infrastructure

42. Morchain, D., 2021: Progress and Challenges in Achieving Vertical Integration in Adaptation Processes. NAP Global Network. https://napglobalnetwork.org/wp-content/uploads/2021/09/napgn-en-2021-vertical-integration-in-adaptation-processes.pdf

43. Scarlett, L. and M. McKinney, 2016: Connecting people and places: The emerging role of network governance in large landscape conservation. *Frontiers in Ecology and the Environment*, **14** (3), 116–125. https://doi.org/10.1002/fee.1247

44. Shames, S. and S.J. Scherr, 2019: Achieving Climate Change Adaptation Through Integrated Landscape Management. Global Commission on Adaptation, Rotterdam, Netherlands and Washington, DC, USA. https://gca.org/reports/achieving-climate-change-adaptation-through-integrated-landscape-management/

45. Ziervogel, G., P. Satyal, R. Basu, A. Mensah, C. Singh, S. Hegga, and T.Z. Abu, 2019: Vertical integration for climate change adaptation in the water sector: Lessons from decentralisation in Africa and India. *Regional Environmental Change*, **19** (8), 2729–2743. https://doi.org/10.1007/s10113-019-01571-y

46. Garcia, C.A., S. Savilaakso, R.W. Verburg, N. Stoudmann, P. Fernbach, S.A. Sloman, G.D. Peterson, M.B. Araújo, J.-F. Bastin, J. Blaser, L. Boutinot, T.W. Crowther, H. Dessard, A. Dray, S. Francisco, J. Ghazoul, L. Feintrenie, E. Hainzelin, F. Kleinschroth, B. Naimi, I.P. Novotny, J. Oszwald, S.A. Pietsch, F. Quétier, B.E. Robinson, M. Sassen, P. Sist, T. Sunderland, C. Vermeulen, L. Wilmé, S.J. Wilson, F. Zorondo-Rodríguez, and P.O. Waeber, 2022: Strategy games to improve environmental policymaking. *Nature Sustainability*, **5** (6), 464–471. https://doi.org/10.1038/s41893-022-00881-0

47. Ringsmuth, A.K., I.M. Otto, B. van den Hurk, G. Lahn, C.P.O. Reyer, T.R. Carter, P. Magnuszewski, I. Monasterolo, J.C.J.H. Aerts, M. Benzie, E. Campiglio, S. Fronzek, F. Gaupp, L. Jarzabek, R.J.T. Klein, H. Knaepen, R. Mechler, J. Mysiak, J. Sillmann, D. Stuparu, and C. West, 2022: Lessons from COVID-19 for managing transboundary climate risks and building resilience. *Climate Risk Management*, **35**, 100395. https://doi.org/10.1016/j.crm.2022.100395

48. Busby, J.W., 2022: The politics of climate change. In: *States and Nature: The Effects of Climate Change on Security*. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/9781108957922

49. DOD, 2021: Department of Defense Climate Risk Analysis. Report Submitted to National Security Council. U.S. Department of Defense, Office of the Undersecretary for Policy, 18 pp. https://media.defense.gov/2021/oct/21/2002877353/-1/-1/0/dod-climate-risk-analysis-final.pdf

50. NIC, 2021: Climate Change and International Responses Increasing Challenges to US National Security Through 2040. NIC-NIE-2021-10030-A. National Intelligence Council. https://www.dni.gov/files/ODNI/documents/assessments/NIE_Climate_Change_and_National_Security.pdf

51. Abel, G.J., M. Brottrager, J. Crespo Cuaresma, and R. Muttarak, 2019: Climate, conflict and forced migration. *Global Environmental Change*, **54**, 239–249. https://doi.org/10.1016/j.gloenvcha.2018.12.003

52. Mach, K.J., C.M. Kraan, W.N. Adger, H. Buhaug, M. Burke, J.D. Fearon, C.B. Field, C.S. Hendrix, J.-F. Maystadt, J. O'Loughlin, P. Roessler, J. Scheffran, K.A. Schultz, and N. von Uexkull, 2019: Climate as a risk factor for armed conflict. *Nature*, **571** (7764), 193–197. https://doi.org/10.1038/s41586-019-1300-6

53. von Uexkull, N. and H. Buhaug, 2021: Security implications of climate change: A decade of scientific progress. *Journal of Peace Research*, **58** (1), 3–17. https://doi.org/10.1177/0022343320984210

54. Daoudy, M., J. Sowers, and E. Weinthal, 2022: What is climate security? Framing risks around water, food, and migration in the Middle East and North Africa. *WIREs Water*, **9** (3), e1582. https://doi.org/10.1002/wat2.1582

55. Dumaine, C., 2022: Adapting to new security realities in a climate-disrupted world. *The Journal of Intelligence, Conflict, and Warfare*, **4** (3), 98–104. https://doi.org/10.21810/jicw.v4i3.4155

56. UNDP, 2022: Special Report: New Threats to Human Security in the Anthropocene: Demanding Greater Solidarity. United Nations Development Programme, New York, NY. https://hs.hdr.undp.org/pdf/srhs2022.pdf

57. Sitati, A., E. Joe, B. Pentz, C. Grayson, C. Jaime, E. Gilmore, E. Galappaththi, A. Hudson, G.N. Alverio, K.J. Mach, M. van Aalst, N. Simpson, P.N. Schwerdtle, S. Templeman, Z. Zommers, I. Ajibade, L.S.S. Chalkasra, P. Umunay, I. Togola, A. Khouzam, G. Scarpa, E.C. de Perez, and Global Adaptation Mapping Initiative Team, 2021: Climate change adaptation in conflict-affected countries: A systematic assessment of evidence. *Discover Sustainability*, **2** (1), 42. https://doi.org/10.1007/s43621-021-00052-9

58. Asaka, J.O., 2021: Climate change-terrorism nexus? A preliminary review/analysis of the literature. *Perspectives on Terrorism*, **15** (1), 81–92. https://www.jstor.org/stable/26984799

59. Erickson, C., 2020: The climate-corruption connection. *Harvard Political Review*. https://harvardpolitics.com/the-climate-corruption-connection/

60. Nest, M., S. Mullard, and C. Wathne, 2020: Corruption and Climate Finance: Implications for Climate Change Interventions. U4 Brief 2020:14. U4 Anti-Corruption Resource Centre, Chr. Michelsen Institute. https://www.u4.no/publications/corruption-and-climate-finance

61. NIC, 2021: Global Trends 2040: A More Contested World. NIC 2021-02339. National Intelligence Council. https://www.dni.gov/files/ODNI/documents/assessments/GlobalTrends_2040.pdf

62. Busby, J.W., 2021: Beyond internal conflict: The emergent practice of climate security. *Journal of Peace Research*, **58** (1), 186–194. https://doi.org/10.1177/0022343320971019

63. Hermans, K. and R. McLeman, 2021: Climate change, drought, land degradation and migration: Exploring the linkages. *Current Opinion in Environmental Sustainability*, **50**, 236–244. https://doi.org/10.1016/j.cosust.2021.04.013

64. UNGA, 2018: Global Compact for Safe, Orderly and Regular Migration: Intergovernmentally Negotiated and Agreed Outcome. United Nations General Assembly, 34 pp. https://refugeesmigrants.un.org/sites/default/files/180713_agreed_outcome_global_compact_for_migration.pdf

65. OSTP, 2023: Congressionally-mandated report on solar radiation modification. White House Office of Science and Technology Policy, Washington, DC, June 30, 2023. https://www.whitehouse.gov/ostp/news-updates/2023/06/30/congressionally-mandated-report-on-solar-radiation-modification/

66. Biermann, F., J. Oomen, A. Gupta, S.H. Ali, K. Conca, M.A. Hajer, P. Kashwan, L.J. Kotzé, M. Leach, D. Messner, C. Okereke, Å. Persson, J. Potočnik, D. Schlosberg, M. Scobie, and S.D. VanDeveer, 2022: Solar geoengineering: The case for an international non-use agreement. *WIREs Climate Change*, **13** (3), e754. https://doi.org/10.1002/wcc.754

67. Reynolds, J.L., 2019: Solar geoengineering to reduce climate change: A review of governance proposals. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, **475** (2229), 20190255. https://doi.org/10.1098/rspa.2019.0255

68. Abrahams, D. and E.R. Carr, 2017: Understanding the connections between climate change and conflict: Contributions from geography and political ecology. *Current Climate Change Reports*, **3** (4), 233–242. https://doi.org/10.1007/s40641-017-0080-z

69. Krampe, F., E.S. Smith, and M.D. Hamidi, 2021: Security implications of climate development in conflict-affected states: Implications of local-level effects of rural hydropower development on farmers in Herat. *Political Geography*, **90**, 102454. https://doi.org/10.1016/j.polgeo.2021.102454

70. Dabelko, G.D., A. Barnhoorn, N. Bell, D. Bell-Moran, E. Broek, A. Eberlein, A. Gadnert, E. Remling, J. Staudenmann, C. Bogner, K. Eklöw, B. Horn, and K. Kim, 2022: Navigating a Just and Peaceful Transition: Environment of Peace (Part 3). SIPRI, Stockholm, Sweden. https://doi.org/10.55163/bhyr7656

71. Scholten, D., M. Bazilian, I. Overland, and K. Westphal, 2020: The geopolitics of renewables: New board, new game. *Energy Policy*, **138**, 111059. https://doi.org/10.1016/j.enpol.2019.111059

72. The White House, 2021: Executive Order on America's Supply Chains. The White House, Washington, DC. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/02/24/executive-order-on-americas-supply-chains/

73. Church, C. and A. Crawford, 2020: Ch. 12. Minerals and the metals for the energy transition: Exploring the conflict implications for mineral-rich, fragile states. In: *The Geopolitics of the Global Energy Transition*. Hafner, M. and S. Tagliapietra, Eds. Springer, Cham, Switzerland, 279–304. https://doi.org/10.1007/978-3-030-39066-2_12

74. USGS, 2022: Mineral Commodity Summaries 2022. U.S. Geological Survey, 202 pp. https://doi.org/10.3133/mcs2022

75. Humphries, M., 2019: Critical Minerals and U.S. Public Policy. CRS Report R45810. Congressional Research Service. https://crsreports.congress.gov/product/pdf/r/r45810

76. DHS, 2021: DHS Strategic Framework for Addressing Climate Change. U.S. Department of Homeland Security. https://www.dhs.gov/publication/dhs-strategic-framework-addressing-climate-change

77. DOD, 2021: Department of Defense Climate Adaptation Plan. Report Submitted to National Climate Task Force and Federal Chief Sustainability Officer. U.S. Department of Defense, Office of the Undersecretary of Defense. https://www.sustainability.gov/pdfs/dod-2021-cap.pdf

78. DOS, 2021: Climate Adaptation and Resilience Plan. U.S. Department of State, 19 pp. https://www.sustainability.gov/pdfs/state-2021-cap.pdf

79. USAID, 2022: Climate Strategy 2022–2030. U.S. Agency for International Development. https://www.usaid.gov/policy/climate-strategy

80. Pinson, A.O., K.D. White, S.A. Moore, S.D. Samuelson, B.A. Thames, P.S. O'Brien, C.A. Hiemstra, P.M. Loechl, and E.E. Ritchie, 2020: Army Climate Resilience Handbook. U.S. Army Corps of Engineers, Washington, DC. https://www.asaie.army.mil/public/es/doc/army_climate_resilience_handbook_change_1.pdf

81. Burnett, M. and K.J. Mach, 2021: A "precariously unprepared" Pentagon? Climate security beliefs and decision-making in the U.S. military. *Global Environmental Change*, **70**, 102345. https://doi.org/10.1016/j.gloenvcha.2021.102345

82. Garfin, G., D.A. Falk, C.D. O'Connor, K. Jacobs, R.D. Sagarin, A.C. Haverland, A. Haworth, A. Baglee, J. Weiss, J. Overpeck, and A.A. Zuñiga-Terán, 2021: A new mission: Mainstreaming climate adaptation in the US Department of Defense. *Climate Services*, **22**, 100230. https://doi.org/10.1016/j.cliser.2021.100230

83. Samaras, C., W.J. Nuttall, and M. Bazilian, 2019: Energy and the military: Convergence of security, economic, and environmental decision-making. *Energy Strategy Reviews*, **26**, 100409. https://doi.org/10.1016/j.esr.2019.100409

84. DOD, 2019: Report to Congress: Department of Defense Arctic Strategy. U.S. Department of Defense, Office of the Under Secretary of Defense for Policy. https://media.defense.gov/2019/jun/06/2002141657/-1/-1/1/2019-dod-arctic-strategy.pdf

85. Burke, M., S.M. Hsiang, and E. Miguel, 2015: Global non-linear effect of temperature on economic production. *Nature*, **527** (7577), 235–239. https://doi.org/10.1038/nature15725

86. Diffenbaugh, N.S. and M. Burke, 2019: Global warming has increased global economic inequality. *Proceedings of the National Academy of Sciences of the United States of America*, **116** (20), 9808–9813. https://doi.org/10.1073/pnas.1816020116

87. AON, 2021: 2021 Weather, Climate and Catastrophe Insight. AON. https://www.aon.com/getmedia/1b516e4d-c5fa-4086-9393-5e6afb0eeded/20220125-2021-weather-climate-catastrophe-insight.pdf.aspx

88. Bevere, L. and F. Remondi, 2022: Natural Catastrophes in 2021: The Floodgates are Open. Swiss Re Institute, Zurich, Switzerland. https://www.swissre.com/institute/research/sigma-research/sigma-2022-01.html

89. WMO, 2021: WMO Atlas of Mortality and Economic Losses From Weather, Climate and Water Extremes (1970–2019). WMO-No. 1267. World Meteorological Organization, Geneva, Switzerland. https://library.wmo.int/index.php?lvl=notice_display&id=21930#.y437p-zmjpq

90. Botzen, W.J.W., F. Estrada, and R.S.J. Tol, 2021: Methodological issues in natural disaster loss normalisation studies. *Environmental Hazards*, **20** (2), 112–115. https://doi.org/10.1080/17477891.2020.1830744

91. Pielke, R., 2021: Economic 'normalisation' of disaster losses 1998–2020: A literature review and assessment. *Environmental Hazards*, **20** (2), 93–111. https://doi.org/10.1080/17477891.2020.1800440

92. Basel Committee on Banking Supervision, 2021: Climate-Related Risk Drivers and Their Transmission Channels. Bank for International Settlements. https://www.bis.org/bcbs/publ/d517.pdf

93. IMPAX Asset Management, 2020: Physical Climate Risks: Designing a Resilient Response to the Inevitable Impact of Climate Change. IMPAX Asset Management Group, 18 pp. https://impaxam.com/wp-content/uploads/2020/09/20200924_physical_climate_risk.pdf

94. Schinko, T., L. Drouet, Z. Vrontisi, A. Hof, J. Hinkel, J. Mochizuki, V. Bosetti, K. Fragkiadakis, D. van Vuuren, and D. Lincke, 2020: Economy-wide effects of coastal flooding due to sea level rise: A multi-model simultaneous treatment of mitigation, adaptation, and residual impacts. *Environmental Research Communications*, **2** (1), 015002. https://doi.org/10.1088/2515-7620/ab6368

95. Statista, 2023: Foreign Direct Investment Position of the United States Abroad from 2000 to 2022. Statista. https://www.statista.com/statistics/188571/united-states-direct-investments-abroad-since-2000/

96. U.S. Census Bureau, 2023: Annual 2022 Press Highlights. U.S. Department of Commerce, U.S. Census Bureau. https://www.census.gov/foreign-trade/statistics/highlights/AnnualPressHighlights.pdf

97. BEA, 2023: Table 1. U.S. International Trade in Goods and Services: Exports, Imports, and Balances. U.S. Department of Commerce, Bureau of Economic Analysis. https://www.bea.gov/sites/default/files/2023-09/trad-time-series-0723.xlsx

98. Mallucci, E., 2020: Natural Disasters, Climate Change, and Sovereign Risk. International Finance Discussion Papers 1291r1. Board of Governors of the Federal Reserve System, Washington, DC. https://doi.org/10.17016/ifdp.2020.1291r1

99. Phan, T. and F.F. Schwartzman, 2023: Climate Defaults and Financial Adaptation. Working Paper No. 23-06. Federal Reserve Bank of Richmond. https://doi.org/10.21144/wp23-06

100. Liefert, W.M., L. Mitchell, and R. Seeley, 2021: Economic Crises in Foreign Markets Reduce U.S. Agricultural Exports. U.S. Department of Agriculture, Economic Research Service. https://www.ers.usda.gov/amber-waves/2021/april/economic-crises-in-foreign-markets-reduce-us-agricultural-exports/

101. Swiss Re, 2021: The Economics of Climate Change: No Action Not an Option. Swiss Re Institute. https://www.swissre.com/dam/jcr:e73ee7c3-7f83-4c17-a2b8-8ef23a8d3312/swiss-re-institute-expertise-publication-economics-of-climate-change.pdf

102. Cruz, J.-L. and E. Rossi-Hansberg, 2021: The Economic Geography of Global Warming. NBER Working Paper No. 28466. National Bureau of Economic Research. https://doi.org/10.3386/w28466

103. Semieniuk, G., E. Campiglio, J.-F. Mercure, U. Volz, and N.R. Edwards, 2021: Low-carbon transition risks for finance. *WIREs Climate Change*, **12** (1), e678. https://doi.org/10.1002/wcc.678

104. OECD, 2018: Climate-Resilient Infrastructure. OECD Environment Policy Paper No. 14. Organisation for Economic Co-Operation and Development. https://www.oecd.org/environment/cc/policy-perspectives-climate-resilient-infrastructure.pdf

105. Bland, R., A. Granskog, and T. Nauclér, 2022: Accelerating Toward Net Zero: The Green Business Building Opportunity. McKinsey Sustainability, 8 pp. https://www.mckinsey.com/capabilities/sustainability/our-insights/accelerating-toward-net-zero-the-green-business-building-opportunity

106. OECD, 2022: *Aggregate Trends of Climate Finance Provided and Mobilised by Developed Countries in 2013–2020. Climate Finance and the USD 100 Billion Goal.* OECD Publishing, Paris, France, 25 pp. https://doi.org/10.1787/d28f963c-en

107. UNEP, 2021: Public-Private Partnerships Could Play Key Role in Combatting Deforestation. United Nations Environment Programme. https://www.unep.org/news-and-stories/story/public-private-partnerships-could-play-key-role-combatting-deforestation

108. IFC, 2016: Climate Investment Opportunities in Emerging Markets: An IFC Analysis. International Finance Corporation, Washington, DC. https://documents1.worldbank.org/curated/en/602971510740408248/pdf/121277-WP-IFC-Climate-Investment-Opportunity-Report-Dec-PUBLIC.pdf

109. GEF, 2019: Advances in Blended Finance: GEF's Solutions to Protect the Global Environment. Global Environment Facility, 24 pp. https://www.thegef.org/publications/advances-blended-finance-gefs-solutions-protect-global-environment

110. Rode, J., A. Pinzon, M.C.C. Stabile, J. Pirker, S. Bauch, A. Iribarrem, P. Sammon, C.A. Llerena, L. Muniz Alves, C.E. Orihuela, and H. Wittmer, 2019: Why 'blended finance' could help transitions to sustainable landscapes: Lessons from the Unlocking Forest Finance project. *Ecosystem Services*, **37**, 100917. https://doi.org/10.1016/j.ecoser.2019.100917

111. TFA, 2022: Forest-Positive Collective Action for Deforestation-Free Commodities Supply Chains. Tropical Forest Alliance, accessed September 8, 2022. https://www.tropicalforestalliance.org/

112. BASE, 2022: The Next-Leap On-Climate: Creating an Enabling Environment for Youth Led Action. BASE. https://energy-base.org/news/the-next-leap-on-climate-creating-an-enabling-environment-for-youth-led-action/

113. Makower, J., 2022: State of Green Business 2022. GreenBiz Group, 51 pp. https://www.greenbiz.com/article/state-green-business-2022

114. Crick, F., K.E. Gannon, M. Diop, and M. Sow, 2018: Enabling private sector adaptation to climate change in sub-Saharan Africa. *WIREs Climate Change*, **9** (2), e505. https://doi.org/10.1002/wcc.505

115. Stenek, V., J.C. Amado, and D. Greenall, 2013: Enabling Environment for Private Sector Adaptation: An Index Assessment Framework. International Finance Corporation, Climate Business Department, Washington, DC. https://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/climate+business/resources/enabling+environment+for+private+sector+adaptation

116. Tall, A., S. Lynagh, C.B. Vecchi, P. Bardouille, F.M. Pino, E. Shabahat, V. Stenek, F. Stewart, S. Power, C. Paladines, P. Neves, and L. Kerr, 2021: Enabling Private Investment in Climate Adaptation & Resilience. World Bank Group and Global Facility for Disaster Reduction and Recovery. https://openknowledge.worldbank.org/entities/publication/6219bf23-87e1-5f30-aaf9-30e0cd793ce3

117. Buchner, B., B. Naran, P. Fernandes, R. Padmanabhi, P. Rosane, M. Solomon, S. Stout, C. Strinati, R. Tolentino, G. Wakaba, Y. Zhu, C. Meattle, and S. Guzmán, 2021: Global Landscape of Climate Finance 2021. Climate Policy Initiative. https://www.climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2021/

118. Naran, B., J. Connolly, P. Rosane, D. Wignarajah, E. Wakaba, and B. Buchner, 2022: Global Landscape of Climate Finance: A Decade of Data 2011–2020. Climate Policy Initiative. https://www.climatepolicyinitiative.org/wp-content/uploads/2022/10/Global-Landscape-of-Climate-Finance-A-Decade-of-Data.pdf

119. European Commission, n.d.: Carbon Border Adjustment Mechanism [Webpage], accessed May 5, 2023. https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

120. Kuusi, T., M. Björklund, V. Kaitila, K. Kokko, M. Lehmus, M. Mehling, T. Oikarinen, J. Pohjola, S. Soimakallio, and M. Wang, 2020: Carbon Border Adjustment Mechanisms and Their Economic Impact on Finland and the EU. Prime Minister's Office, Helsinki, Finland. http://urn.fi/urn:isbn:978-952-287-922-6

121. Climate Action 100+, n.d.: The Business Case [Webpage]. https://www.climateaction100.org/business-case

122. KPMG, 2020: The Business Case for Climate Action. KPMG Sustainable Futures, 28 pp. https://assets.kpmg/content/dam/kpmg/ie/pdf/2020/01/ie-the-business-case-for-climate-action.pdf

123. PPG, 2021: The Business Case for Climate Action. Partners in Project Green. https://partnersinprojectgreen.com/resources/the-business-case-for-climate-action/#the_business_case_for_climate_action

124. GFANZ, 2021: The Glasgow Financial Alliance for Net Zero: Our Progress and Plan Towards a Net-Zero Global Economy. Glasgow Financial Alliance for Net Zero. https://assets.bbhub.io/company/sites/63/2021/11/GFANZ-Progress-Report.pdf

125. Tiseo, I., 2023: Global Carbon Market Size 2018–2021. Statista. https://www.statista.com/statistics/1334848/global-carbon-market-size-value/

126. ADB, 2020: Decoding Article 6 of the Paris Agreement, Version II. Asian Development Bank. https://doi.org/10.22617/tcs200411-2

127. Di Leva, C.E. and S. Vaughan, 2021: The Paris Agreement's New Article 6 Rules: The Promise and Challenge of Carbon Market and Non-market Approaches. International Institute for Sustainable Development. https://www.iisd.org/articles/paris-agreement-article-6-rules

128. IETA, 2023: The Evolving Carbon Credit Market. International Emissions Trading Association. https://www.ieta.org/resources/reports/the-evolving-voluntary-carbon-market-paper/

129. Blaufelder, C., C. Levy, P. Mannion, and D. Pinner, 2021: A Blueprint for Scaling Voluntary Carbon Markets to Meet the Climate Challenge. McKinsey Sustainability, 7 pp. https://www.mckinsey.com/capabilities/sustainability/our-insights/a-blueprint-for-scaling-voluntary-carbon-markets-to-meet-the-climate-challenge

130. EDF and ENGIE Impact, 2021: Trends in the Voluntary Carbon Markets: Where We Are and What's Next. Environmental Defense Fund and ENGIE Impact, 5 pp. https://www.edf.org/content/trends-voluntary-carbon-market-where-we-are-and-whats-next

131. Trove Research, 2021: Future Size of the Voluntary Carbon Market. Trove Research, Harpenden, UK, 10 pp. https://trove-research.com/report/future-size-of-the-voluntary-carbon-market/

132. TSVCM, 2021: Final Report. Taskforce on Scaling Voluntary Carbon Markets. https://www.iif.com/portals/1/files/tsvcm_report.pdf

133. Carton, W., J.F. Lund, and K. Dooley, 2021: Undoing equivalence: Rethinking carbon accounting for just carbon removal. *Frontiers in Climate*, **3**, 664130. https://doi.org/10.3389/fclim.2021.664130

134. Smith, S.M., 2021: A case for transparent net-zero carbon targets. *Communications Earth & Environment*, **2** (1), 24. https://doi.org/10.1038/s43247-021-00095-w

135. TCFD, 2022: Support the TCFD: TCFD Supporters Around the World. Task Force on Climate-Related Financial Disclosures. https://www.fsb-tcfd.org/support-tcfd/

136. FSOC, 2021: Report on Climate-Related Financial Risk. Financial Stability Oversight Council, Washington, DC. https://home.treasury.gov/system/files/261/FSOC-Climate-Report.pdf

137. G7, 2021: Climate and environment ministers' meeting communiqué. *G7 Ministers for Climate and Environment Virtual Meeting*, London, UK, 20–21 May 2021, 27 pp. http://www.g7.utoronto.ca/environment/2021-g7-climate-environment-communique.pdf

138. NGFS, 2021: Guide on Climate-Related Disclosure for Central Banks. Network for Greening the Financial System, 38 pp. https://www.ngfs.net/en/guide-climate-related-disclosure-central-banks

139. SEC, 2022: The Enhancement and Standardization of Climate-Related Disclosures for Investors. Securities and Exchange Commission, 490 pp. https://www.sec.gov/rules/proposed/2022/33-11042.pdf

140. TCFD, 2021: 2021 Status Report. Task Force on Climate-Related Financial Disclosures. https://assets.bbhub.io/company/sites/60/2021/07/2021-TCFD-Status_Report.pdf

141. Bingler, J.A., M. Kraus, M. Leippold, and N. Webersinke, 2022: Cheap talk and cherry-picking: What ClimateBERT has to say on corporate climate risk disclosures. *Finance Research Letters*, **47**, 102776. https://doi.org/10.1016/j.frl.2022.102776

142. Mattison, R., B. Longevialle, B. Bastit, L. Hall, L. Ly, P. Munday, and B. Thomson, 2022: Key Trends That Will Drive the ESG Agenda in 2022. S&P Global. https://www.spglobal.com/esg/insights/featured/special-editorial/key-esg-trends-in-2022

143. SBTi, 2022: Science-Based Net-Zero: Scaling Urgent Corporate Climate Action Worldwide. Science Based Targets Initiative. https://sciencebasedtargets.org/resources/files/SBTiProgressReport2021.pdf

144. The Economist, 2022: A broken system needs urgent repairs. *The Economist*, July 21 2022. https://www.economist.com/special-report/2022/07/21/a-broken-system-needs-urgent-repairs

145. Kinywamaghana, A.B., 2022: Are SMEs ready for ESG reporting? Opportunities and challenges. *Frankfurt School Blog*. Frankfurt School of Finance and Management. https://blog.frankfurt-school.de/are-smes-ready-for-esg-reporting-opportunities-and-challenges/

146. Klusak, P., M. Agarwala, M. Burke, M. Kraemer, and K. Mohaddes, 2021: Rising Temperatures, Falling Ratings: The Effect of Climate Change on Sovereign Creditworthiness. Bennett Institute Working Paper. University of Cambridge, Bennett Institute for Public Policy. https://www.bennettinstitute.cam.ac.uk/publications/rising-temperatures-falling-ratings/

147. IIGCC, 2022: Working Towards a Climate Resilience Investment Framework. Institutional Investors Group on Climate Change, London, UK. https://www.iigcc.org/resources/working-towards-a-climate-resilience-investment-framework

148. Trabacchi, C., J. Koh, S. Shi, and T. Guelig, 2020: Adaptation Solutions Taxonomy. Cabrera, M.M., Ed. Inter-American Development Bank, 69 pp. https://doi.org/10.18235/0002556

149. The Lightsmith Group, 2022: Lightsmith Group Closes Inaugural $186 Million Growth Equity Climate Fund, the First to Focus on Climate Resilience and Adaptation. The Lightsmith Group, New York, NY. https://lightsmithgp.com/news-posts/lightsmith-group-closes-inaugural-186-million-growth-equity-climate-fund-the-first-to-focus-on-climate-resilience-and-adaptation/

150. Anderson, J., 2021: To tackle climate change, take on corruption. *World Bank Blogs*. World Bank Group. https://blogs.worldbank.org/climatechange/tackle-climate-change-take-corruption

151. Sperling, L.I., 2021: Whistleblower protection in a systems approach to sustainable development. *Whistleblower Network News*, December 21, 2021. https://whistleblowersblog.org/opinion/whistleblower-protection-in-a-systems-approach-to-sustainable-development/

152. Sweeney, G., R. Dobson, K. Despota, and D. Zinnbauer, Eds., 2011: *Global Corruption Report: Climate Change*. Transparency International, London, UK and Washington, DC, 400 pp. https://images.transparencycdn.org/images/2011_GCRclimatechange_EN.pdf

153. Birkmann, J., E. Liwenga, R. Pandey, E. Boyd, R. Djalante, F. Gemenne, W.L. Filho, P.F. Pinho, L. Stringer, and D.Wrathall, 2022: Ch. 8. Poverty, livelihoods and sustainable development. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Pörtner, H.-O., D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama, Eds. Cambridge University Press, Cambridge, UK and New York, NY, 1171–1274. https://doi.org/10.1017/9781009325844.010

154. Obersteiner, M., B. Walsh, S. Frank, P. Havlík, M. Cantele, J. Liu, A. Palazzo, M. Herrero, Y. Lu, A. Mosnier, H. Valin, K. Riahi, F. Kraxner, S. Fritz, and D. van Vuuren, 2016: Assessing the land resource–food price nexus of the Sustainable Development Goals. *Science Advances*, **2** (9), e1501499. https://doi.org/10.1126/sciadv.1501499

155. Scobie, M., 2016: Policy coherence in climate governance in Caribbean small island developing states. *Environmental Science & Policy*, **58**, 16–28. https://doi.org/10.1016/j.envsci.2015.12.008

156. Smith, M.R. and S.S. Myers, 2018: Impact of anthropogenic CO_2 emissions on global human nutrition. *Nature Climate Change*, **8** (9), 834–839. https://doi.org/10.1038/s41558-018-0253-3

157. Wheeler, T. and J. von Braun, 2013: Climate change impacts on global food security. *Science*, **341** (6145), 508–13. https://doi.org/10.1126/science.1239402

158. Ermolina, M., A. Matveevskaya, and M. Baranuk, 2021: Ch. 20. Climate change and the UN 2030 agenda for sustainable development. In: *Proceedings of Topical Issues in International Political Geography*. Springer, Cham, Switzerland, 226–237. https://doi.org/10.1007/978-3-030-78690-8_20

159. Fuso Nerini, F., B. Sovacool, N. Hughes, L. Cozzi, E. Cosgrave, M. Howells, M. Tavoni, J. Tomei, H. Zerriffi, and B. Milligan, 2019: Connecting climate action with other Sustainable Development Goals. *Nature Sustainability*, **2** (8), 674–680. https://doi.org/10.1038/s41893-019-0334-y

160. Sachs, J., C. Kroll, G. Lafortune, G. Fuller, and F. Woelm, 2022: *Sustainable Development Report 2022*. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/9781009210058

161. Hallegatte, S. and J. Rozenberg, 2017: Climate change through a poverty lens. *Nature Climate Change*, **7** (4), 250–256. https://doi.org/10.1038/nclimate3253

162. Atela, J.O., C.H. Quinn, A.A. Arhin, L. Duguma, and K.L. Mbeva, 2017: Exploring the agency of Africa in climate change negotiations: The case of REDD+. *International Environmental Agreements: Politics, Law and Economics*, **17** (4), 463–482. https://doi.org/10.1007/s10784-016-9329-6

163. Gereke, M. and T. Brühl, 2019: Unpacking the unequal representation of Northern and Southern NGOs in international climate change politics. *Third World Quarterly*, **40** (5), 870–889. https://doi.org/10.1080/01436597.2019.1596023

164. Roger, C. and S. Belliethathan, 2016: Africa in the global climate change negotiations. *International Environmental Agreements: Politics, Law and Economics*, **16** (1), 91–108. https://doi.org/10.1007/s10784-014-9244-7

165. Wunder, S., F. Noack, and A. Angelsen, 2018: Climate, crops, and forests: A pan-tropical analysis of household income generation. *Environment and Development Economics*, **23** (3), 279–297. https://doi.org/10.1017/s1355770x18000116

166. Dooley, K., C. Holz, S. Kartha, S. Klinsky, J.T. Roberts, H. Shue, H. Winkler, T. Athanasiou, S. Caney, E. Cripps, N.K. Dubash, G. Hall, P.G. Harris, B. Lahn, D. Moellendorf, B. Müller, A. Sagar, and P. Singer, 2021: Ethical choices behind quantifications of fair contributions under the Paris Agreement. *Nature Climate Change*, **11** (4), 300–305. https://doi.org/10.1038/s41558-021-01015-8

167. Mattar, S.D., T. Jafry, P. Schröder, and Z. Ahmad, 2021: Climate justice: Priorities for equitable recovery from the pandemic. *Climate Policy*, **21** (10), 1307–1317. https://doi.org/10.1080/14693062.2021.1976095

168. Carleton, T.A., A. Jina, M.T. Delgado, M. Greenstone, T. Houser, S.M. Hsiang, A. Hultgren, R.E. Kopp, K.E. McCusker, I.B. Nath, J. Rising, A. Rode, H.K. Seo, A. Viaene, J. Yuan, and A.T. Zhang, 2020: Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits. Working Paper 27599. National Bureau of Economic Research. https://doi.org/10.3386/w27599

169. IPCC, 2023: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Lee, H. and J. Romero, Eds. Intergovernmental Panel on Climate Change, Geneva, Switzerland, 184 pp. https://doi.org/10.59327/IPCC/AR6-9789291691647

170. O'Neill, B., M. van Aalst, Z. Zaiton Ibrahim, L. Berrang Ford, S. Bhadwal, H. Buhaug, D. Diaz, K. Frieler, M. Garschagen, A. Magnan, G. Midgley, A. Mirzabaev, A. Thomas, and R. Warren, 2022: Ch. 16. Key risks across sectors and regions. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Pörtner, H.-O., D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama, Eds. Cambridge University Press, Cambridge, UK and New York, NY, USA, 2411–2538. https://doi.org/10.1017/9781009325844.025

171. CFA, 2020: Understanding the Role of Climate Risk Transparency on Capital Pricing for Developing Countries. Findings Report. Climate Finance Advisors, Benefit LLC, Washington, DC. https://climatefinanceadvisors.com/wp-content/uploads/2020/10/FCDO-Report_Findings-Report_11.25.2020.pdf

172. Kornejew, M., J. Rentschler, and S. Hallegatte, 2019: Well Spent: How Governance Determines the Effectiveness of Infrastructure Investments. Policy Research Working Paper 8894. World Bank Group, Washington, DC. https://openknowledge.worldbank.org/handle/10986/31914?locale-attribute=en

173. Richmond, M., J. Choi, P. Rosane, M. Solomon, B. Tonkonogy, D. Molloy, F. Larrain, and J.J. Rae, 2021: Adaptation Finance in the Context of COVID-19. Global Center on Adaptation and Climate Policy Initiative, 64 pp. https://gca.org/wp-content/uploads/2021/01/GCA-Adaption-in-Finance-Report.pdf

174. Williams, S., M. Nitschke, B.Y. Wondmagegn, M. Tong, J. Xiang, A. Hansen, J. Nairn, J. Karnon, and P. Bi, 2022: Evaluating cost benefits from a heat health warning system in Adelaide, South Australia. *Australian and New Zealand Journal of Public Health*, **46** (2), 149–154. https://doi.org/10.1111/1753-6405.13194

175. Philip, P., C. Ibrahim, and C. Hodges, 2022: The Turning Point: A Global Summary. Deloitte. https://www2.deloitte.com/content/dam/Deloitte/global/Documents/gx-global-turning-point-report.pdf

176. Barakat, S. and S. Milton, 2020: Localisation across the humanitarian-development-peace nexus. *Journal of Peacebuilding & Development*, **15** (2), 147–163. https://doi.org/10.1177/1542316620922805

177. Berrang-Ford, L., A.R. Siders, A. Lesnikowski, A.P. Fischer, M.W. Callaghan, et al., 2021: A systematic global stocktake of evidence on human adaptation to climate change. *Nature Climate Change*, **11** (11), 989–1000. https://doi.org/10.1038/s41558-021-01170-y

178. Peters, K., L. Langston, T. Tanner, and A. Bahadur, 2016: Resilience Across the Post-2015 Frameworks: Towards Coherence. Overseas Development Institute. https://odi.org/en/publications/resilience-across-the-post-2015-frameworks-towards-coherence/

179. Tompkins, E.L., K. Vincent, R.J. Nicholls, and N. Suckall, 2018: Documenting the state of adaptation for the global stocktake of the Paris Agreement. *WIREs Climate Change*, **9** (5), e545. https://doi.org/10.1002/wcc.545

180. Werners, S.E., E. Sparkes, E. Totin, N. Abel, S. Bhadwal, J.R.A. Butler, S. Douxchamps, H. James, N. Methner, J. Siebeneck, L.C. Stringer, K. Vincent, R.M. Wise, and M.G.L. Tebboth, 2021: Advancing climate resilient development pathways since the IPCC's Fifth Assessment Report. *Environmental Science & Policy*, **126**, 168–176. https://doi.org/10.1016/j.envsci.2021.09.017

181. de Carvalho, G., C. de Coning, and L. Connolly, 2014: Creating an Enabling Peacebuilding Environment: How Can External Actors Contribute to Resilience? The African Centre for the Constructive Resolution of Disputes, 9 pp. https://www.accord.org.za/publication/creating-an-enabling-peacebuilding-environment/

182. Spencer, B., J. Lawler, C. Lowe, L. Thompson, T. Hinckley, S.-H. Kim, S. Bolton, S. Meschke, J.D. Olden, and J. Voss, 2017: Case studies in co-benefits approaches to climate change mitigation and adaptation. *Journal of Environmental Planning and Management*, **60** (4), 647–667. https://doi.org/10.1080/09640568.2016.1168287

183. Pelling, M., K. O'Brien, and D. Matyas, 2015: Adaptation and transformation. *Climatic Change*, **133** (1), 113–127. https://doi.org/10.1007/s10584-014-1303-0

184. Saxena, A., K. Qui, and S.-a. Robinson, 2018: Knowledge, attitudes and practices of climate adaptation actors towards resilience and transformation in a 1.5°C world. *Environmental Science & Policy*, **80**, 152–159. https://doi.org/10.1016/j.envsci.2017.11.001

185. Schipper, E.L.F., A. Revi, B.L. Preston, E.R. Carr, S.H. Eriksen, L.R. Fernandez-Carril, B.C. Glavovic, N.J.M. Hilmi, D. Ley, R. Mukerji, M.S.M. de Araujo, R. Perez, S.K. Rose, and P.K. Singh, 2022: Ch. 18. Climate resilient development pathways. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Pörtner, H.-O., D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama, Eds. Cambridge University Press, Cambridge, UK and New York, NY, USA, 2655–2807. https://doi.org/10.1017/9781009325844.027

186. Leitch, A.M., J.P. Palutikof, D. Rissik, S.L. Boulter, F.N. Tonmoy, S. Webb, A.C.P. Vidaurre, and M.C. Campbell, 2019: Co-development of a climate change decision support framework through engagement with stakeholders. *Climatic Change*, **153** (4), 587–605. https://doi.org/10.1007/s10584-019-02401-0

187. Woodall, L.C., S. Talma, O. Steeds, P. Stefanoudis, M.-M. Jeremie-Muzungaile, and A. de Comarmond, 2021: Co-development, co-production and co-dissemination of scientific research: A case study to demonstrate mutual benefits. *Biology Letters*, **17** (4), 20200699. https://doi.org/10.1098/rsbl.2020.0699

188. Vincent, K., M. Daly, C. Scannell, and B. Leathes, 2018: What can climate services learn from theory and practice of co-production? *Climate Services*, **12**, 48–58. https://doi.org/10.1016/j.cliser.2018.11.001

189. New, M., D. Reckien, D. Viner, C. Adler, S.-M. Cheong, C. Conde, A. Constable, E.C.d. Perez, A. Lammel, R. Mechler, B. Orlove, and W. Solecki, 2022: Ch. 17. Decision-making options for managing risk. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Pörtner, H.-O., D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, and B. Rama, Eds. Cambridge University Press, Cambridge, UK and New York, NY, USA, 2539–2654. https://doi.org/10.1017/9781009325844.026

190. Singh, C., S. Iyer, M.G. New, R. Few, B. Kuchimanchi, A.C. Segnon, and D. Morchain, 2022: Interrogating 'effectiveness' in climate change adaptation: 11 guiding principles for adaptation research and practice. *Climate and Development*, **14** (7), 650–664. https://doi.org/10.1080/17565529.2021.1964937

191. CRED, 2009: EM-DAT: The International Disaster Database. Centre for Research on the Epidemiology of Disasters, accessed May 5, 2023. https://www.emdat.be/

192. Costinot, A., D. Donaldson, and C. Smith, 2016: Evolving comparative advantage and the impact of climate change in agricultural markets: Evidence from 1.7 million fields around the world. *Journal of Political Economy*, **124** (1), 205–248. https://doi.org/10.1086/684719

193. Gouel, C. and D. Laborde, 2021: The crucial role of domestic and international market-mediated adaptation to climate change. *Journal of Environmental Economics and Management*, **106**, 102408. https://doi.org/10.1016/j.jeem.2020.102408

194. Nath, I., 2021: Climate Change, the Food Problem, and the Challenge of Adaptation through Sectoral Reallocation. Working Paper No. CES-21-29. U.S. Census Bureau, Center for Economic Studies. https://www.census.gov/library/working-papers/2021/adrm/CES-WP-21-29.html

195. Alsina-Pujols, M., 2022: Warming with Borders: Climate Refugees and Carbon Pricing. University of Oslo, Department of Economics. https://www.sv.uio.no/econ/english/research/news-and-events/events/guest-lectures-seminars/job-market/2022/2022-01-25-alsina-pujols.html