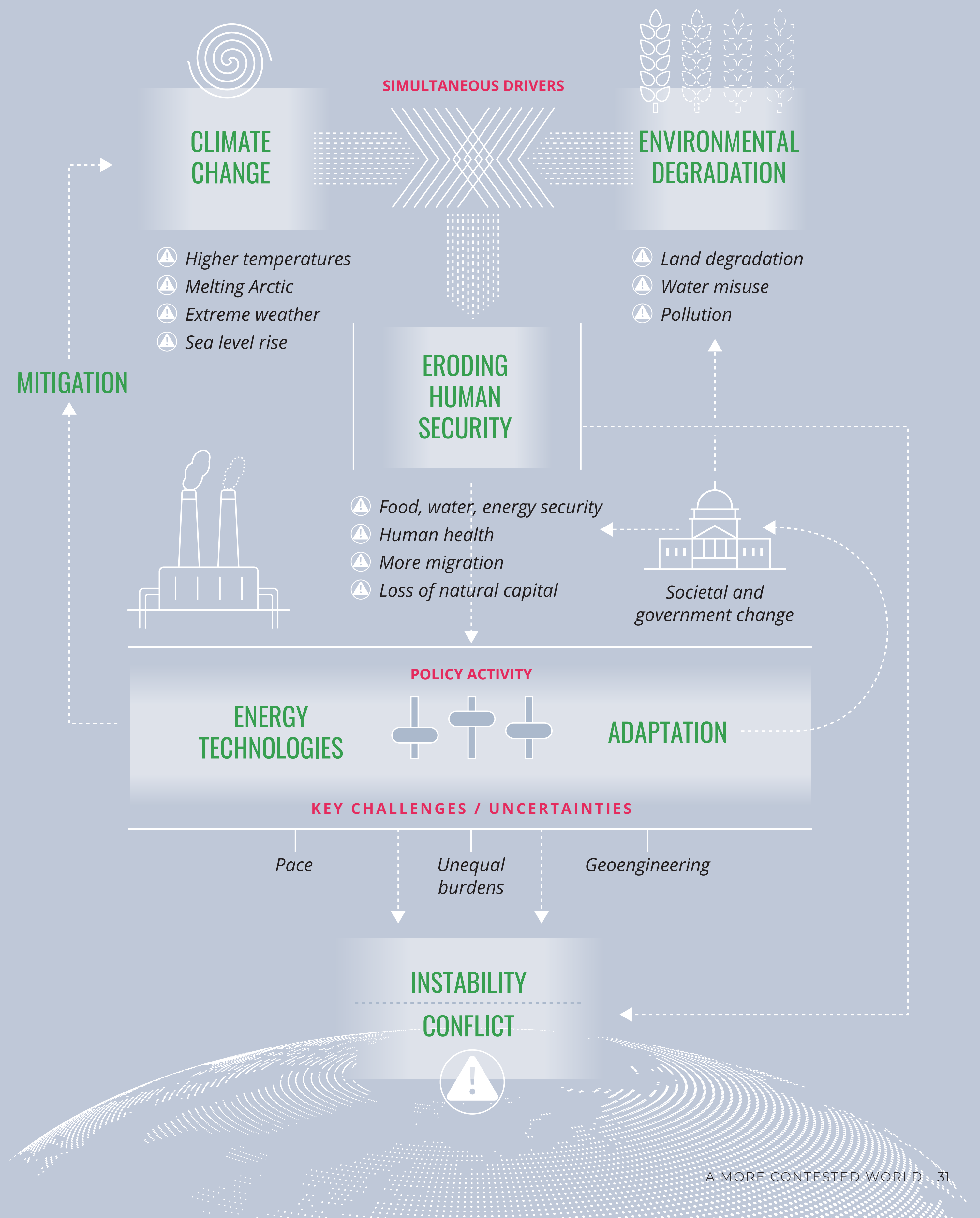
STRUCTURAL FORCES

ENVIRONMENT

Key Takeaways

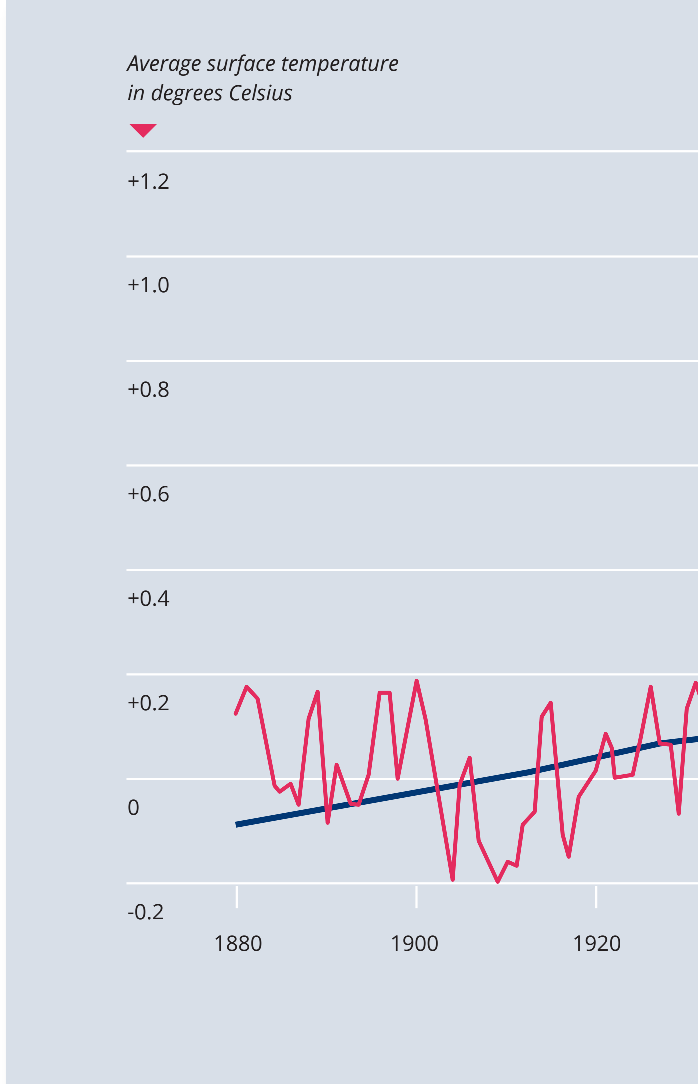
- During the next 20 years, the physical effects from climate change of higher temperatures, sea level rise, and extreme weather events will impact every country. The costs and challenges will disproportionately fall on the developing world, intersecting with environmental degradation to intensify risks to food, water, health, and energy security.
- There will be increased emphasis on mitigating greenhouse gas emissions to achieve net zero with new energy technologies and carbon dioxide removal techniques to meet the Paris Agreement goal of limiting warming to 1.5 degrees Celsius. However, as the world gets closer to exceeding 1.5°C—probably within the next 20 years—calls will increase for geoengineering research and possible deployment to cool the planet, despite possibly dire consequences.
- Debate will increase over how and how fast the world should reach net zero as countries face hard choices over how to implement drastic emissions cuts and adaptive measures. Neither the burdens nor the benefits will be evenly distributed within or between countries, heightening competition, contributing to instability, straining military readiness, and encouraging political discord.

Photo / Pexels


SIMULTANEOUS DRIVERS
CLIMATE CHANGE
ENVIRONMENTAL DEGRADATION
Higher temperatures
Melting Arctic
Extreme weather
Sea level rise
Land degradation
Water misuse
Pollution
MITIGATION
ERODING HUMAN SECURITY
Food, water, energy security
Human health
More migration
Loss of natural capital
Societal and government change
POLICY ACTIVITY
ENERGY TECHNOLOGIES
ADAPTATION
KEY CHALLENGES / UNCERTAINTIES
Pace
Unequal burdens
Geoengineering
INSTABILITY
CONFLICT

The past ten years was the hottest on record, and every decade since the 1960s has been hotter than the previous one.

GLOBAL RISE IN CARBON DIOXIDE AND AVERAGE TEMPERATURE



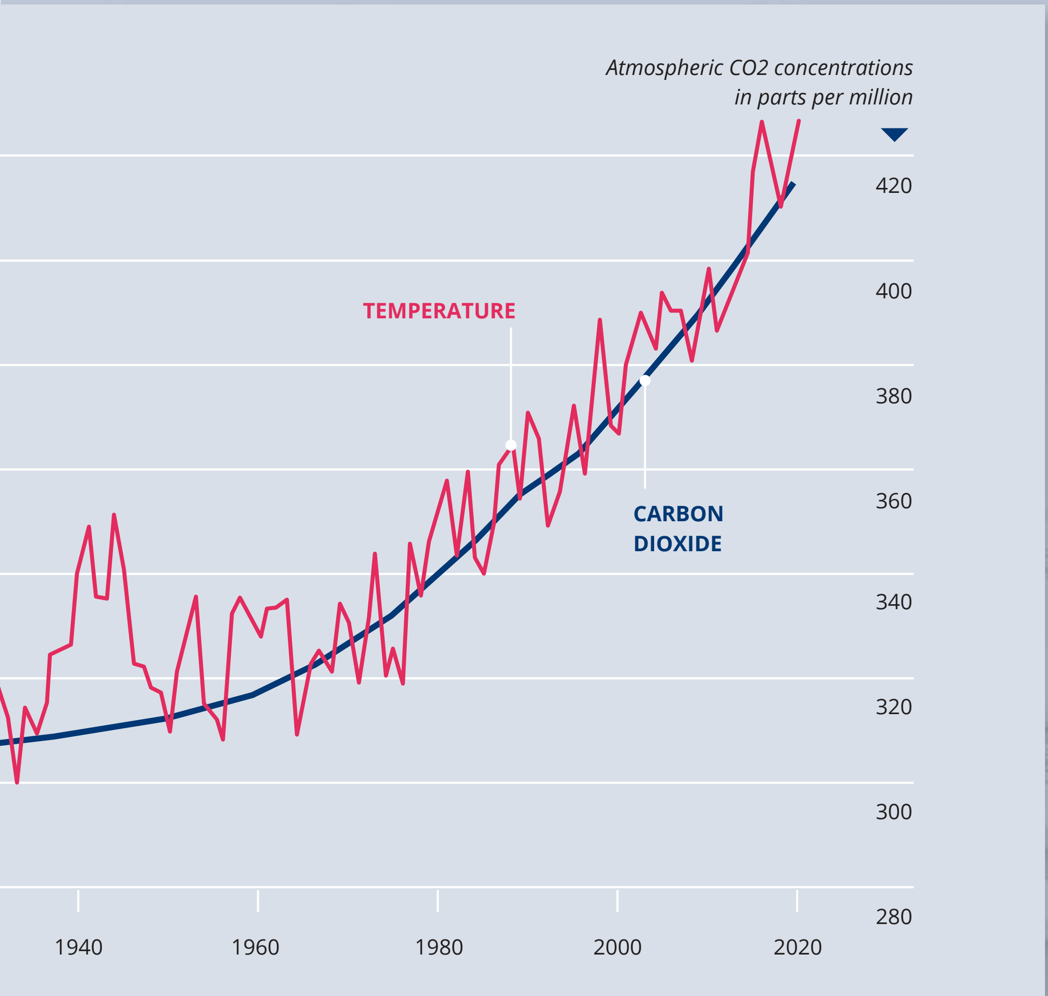
CLIMATE CHANGE HERE AND INTENSIFYING

We are living in a world already affected by climate change caused by growing human-induced concentrations of greenhouse gases in the atmosphere. The world has warmed on average 1.1 degrees Celsius since the late 19th century, causing diminished glaciers and ice caps, higher sea levels, more intense storms and heat waves, and a more acidic ocean, according to the Intergovernmental Panel on Climate Change. The past 10 years were the hottest on record, and every decade since the 1960s has been hotter than the previous one. On the current path, it is probable that within the next 20 years global warming will surpass 1.5°C while heading toward 2°C possibly by mid-century. Cumulative emissions already in the atmosphere will drive temperature increases in the next two decades even if emissions were to reach net zero immediately, according to the US National Climate Assessment.

Physical Effects

The physical effects of a changing climate are likely to gradually intensify during the next two decades compared to the catastrophic impacts modeled for the latter half of the century, should temperature rise continue unabated. No country or region will be immune from the physical effects of climate change and environmental degradation, but the impact will vary—some regions will even see some marginal benefits in the form of longer growing seasons. In general, developing countries will suffer more as they lack the capacity to adapt to climate change and on average are more highly exposed to its effects.

Melting Arctic and Sea Level Rise. Temperatures are warming at three times the global average in the Arctic largely as a result of feedback loops from melting ice and snow cover. This has caused mass loss from ice sheets and glaciers as well as reductions in sea ice extent



Source: NASA GISS, NOAA NCEI, ESRL. https://medialibrary.climatecentral.org/resources/national-and-global-emissions-sources-2020.

This graph illustrates the change in global carbon dioxide concentrations in atmospheric parts per million and in global surface temperature in degrees Celsius relative to pre-Industrial average temperatures. Nineteen of the 20 warmest years have occurred since 2001, and 2020 tied for the hottest year on record.

Willian Justen de Vasconcellos / Unsplash

NARROWING CLIMATE UNCERTAINTIES

Even though the Earth's climate is an extremely complex, interconnected system that is sensitive to small changes, increased data collection, computing power, and sophisticated modeling means that our understanding of climate change has become increasingly strong. Several areas of research are attempting to reduce uncertainty:

Attribution: Scientists are improving their ability to attribute specific events after the fact to climate change. This nascent field, known as extreme event attribution, could change how publics perceive the growing threat and provide a basis for developing countries or impacted communities to claim damages from high emitting countries or their government.

Feedback Loops: Scientists currently have a difficult time projecting when and to what extent positive feedback loops will drive further temperature increases and risk runaway warming. For example, the loss of reflective sea ice will reveal more of the ocean surface, which is dark and absorbs heat faster, in turn causing even more sea ice to melt. Another concerning feedback loop is methane, a powerful greenhouse gas that is released from wetlands, permafrost, and ocean hydrates in response to increased temperatures.

and thickness. Globally, the sea level has risen an average of 8 to 9 inches since the late 19th century; estimates of rise in the next 20 years range from another 3 to 14 inches, which would create additional problems for low lying coastal cities and islands. On land, thawing permafrost is likely to cause increasing damage to infrastructure, including transportation systems, pipelines, and power plants.

More Intense Heat Waves. Outside the Arctic, the fastest warming is projected to occur in central and eastern North America, central Europe, the Mediterranean region (including southern Europe, northern Africa and the Near East), western and central Asia, and southern Africa. The tropics especially are expected to experience widespread extreme heatwaves.

Extreme Weather and Weather Patterns. Warming temperatures are likely to create the atmospheric conditions for more intense and in some cases, more frequent natural disasters, including stronger hurricane-strength storms, coastal flooding, storm surges, and droughts. Traditional weather patterns are also changing—for example, dry areas are expected to become drier, wet areas will become wetter, and precipitation will be less frequent but more intense in some areas.

ADDING TO ENVIRONMENTAL DEGRADATION

During the next two decades, population growth, rapid urbanization, and poor land and resource management will increasingly intersect with and exacerbate climate change effects in many countries, particularly in the developing world. With coastal cities growing, more people than ever will be threatened by a combination of storm surges and sea level rise that worsen existing coastal erosion.

Land Degradation. The expansion and unsustainable management of agriculture and forestry practices degrade land, and both contribute to and intensify the effects of climate change. A 2019 study found that global deforestation and land degradation each contributed to about 10 percent of all human-induced greenhouse gas emissions by releasing carbon stored in the trees and the soil.

Water Misuse. Poor water governance within and between states will remain the primary driver of water stress during the next two decades. As precipitation declines or becomes more erratic, population growth, economic development, and continued inefficient irrigation and agricultural practices will increase demand. In many river basins, upstream countries are building dams and altering water sources with little or no consultation with their downstream neighbors, such as the Grand Ethiopian Renaissance Dam, increasing the risk of conflict.

Pollution. Although air and water pollution have decreased in many high-income countries since a peak in the 20th century, they continue to grow globally as the number of middle-income countries has increased; for instance, 80 percent of industrial and municipal wastewaters are discharged untreated into waterways. Similar to other environmental factors, air pollution and climate change influence each other through complex interactions in the atmosphere. Climate change will lead to more stagnation events—stationary domes of hot air that can cause air pollutants to get trapped and persist in the lower atmosphere—and will worsen air quality by increasing the frequency of wild fires.

ERODING HUMAN SECURITY

The physical impacts of a warmer world, combined with environmental degradation, are likely to lead to an array of human security challenges, primarily but not exclusively in developing countries in the near term. According to a 2018 study, 36 percent of cities globally face acute environmental stress from droughts, floods, and cyclones; climate change will add to these. These challenges will compound one another in coming years; as extreme events become more intense and more frequent, societies may struggle to recover from one event before the next one hits.

Exacerbating Food and Water Insecurity. Changing precipitation patterns, rising temperatures, increased extreme weather events, and saltwater intrusion into soil and water systems from rising seas and storm surges are likely to exacerbate food and water insecurity in some countries during the next two decades. Regions that remain dependent on rain-fed agriculture will be particularly vulnerable, such as Sub-Saharan Africa, Central America, some areas of Argentina and Brazil, parts of the Andean region, South Asia, and Australia. By contrast, some higher latitude regions such as Canada, northern Europe, and Russia may benefit from global warming by lengthened growing seasons.

Fisheries are also under threat from severe overfishing that climate change will further stress through oxygen depletion, rapid warming, and ocean acidification. Fishermen have to go further to catch fewer and smaller fish, potentially venturing into the territorial waters of other countries. In addition, warming ocean temperatures threaten to kill many more coral reefs—already they have declined by 30 to 50 percent, and at 1.5°C warming, they could decline by 70 to 90 percent—further threatening fishing and tourism industries.

Threats to Human Health. Decreased water, air, and food quality, along with changes in disease vectors and water-borne pathogens, all threaten human life. Death rates from pollution vary significantly across the world—typically highest in middle-income countries in East and South Asia. In addition, extreme weather and disasters often kill people and disrupt health infrastructure and prevent access to care. Climate change is expected to change the geographic range and in some cases frequency of disease outbreaks affecting humans, animals, and plants, including those that are vector-borne (West Nile, malaria, Dengue), waterborne (cholera), airborne (influenza, hantavirus), and food-borne (salmonella).

Loss of Biodiversity. The variability among all living organisms—known as biodiversity—is declining faster than at any point in human history, risking food and health security and undermining global resilience. Warming temperatures are likely to lead to the extinction of plants and animals that can no longer survive in their traditional habitats or shift quickly to new locations as well as encourage the spread of invasive species that choke out native organisms.

Increased Migration. Extreme weather events increase the risk of more environmentally-induced migration, which usually occurs within states as affected populations move to nearby communities, often temporarily. Climate change probably will exacerbate this as sea level rise or extreme heat makes certain locales permanently uninhabitable, although mainly after 2040, possibly causing permanent migration and movement to other states.

MITIGATION GAINING TRACTION

Efforts to set a path toward net zero greenhouse gas emissions will intensify during the coming decade and spark increased debate about how and how soon to achieve this goal. The 2015 Paris Agreement set a global goal of limiting warming to less than 2°C, preferably to 1.5°C, and resulted in countries volunteering modest targets to reduce or establish a peak for their emissions. Although developed country emissions have continued to decline largely because of increased energy efficiency and use of natural gas, and the COVID-19 pandemic also caused a brief drop in global emissions—overall emissions have continued to increase. This trend has led to a growing number of countries making more ambitious pledges to become carbon neutral—such as Chile, the European Union (EU), Japan, New Zealand, and South Korea by 2050, and China by 2060.

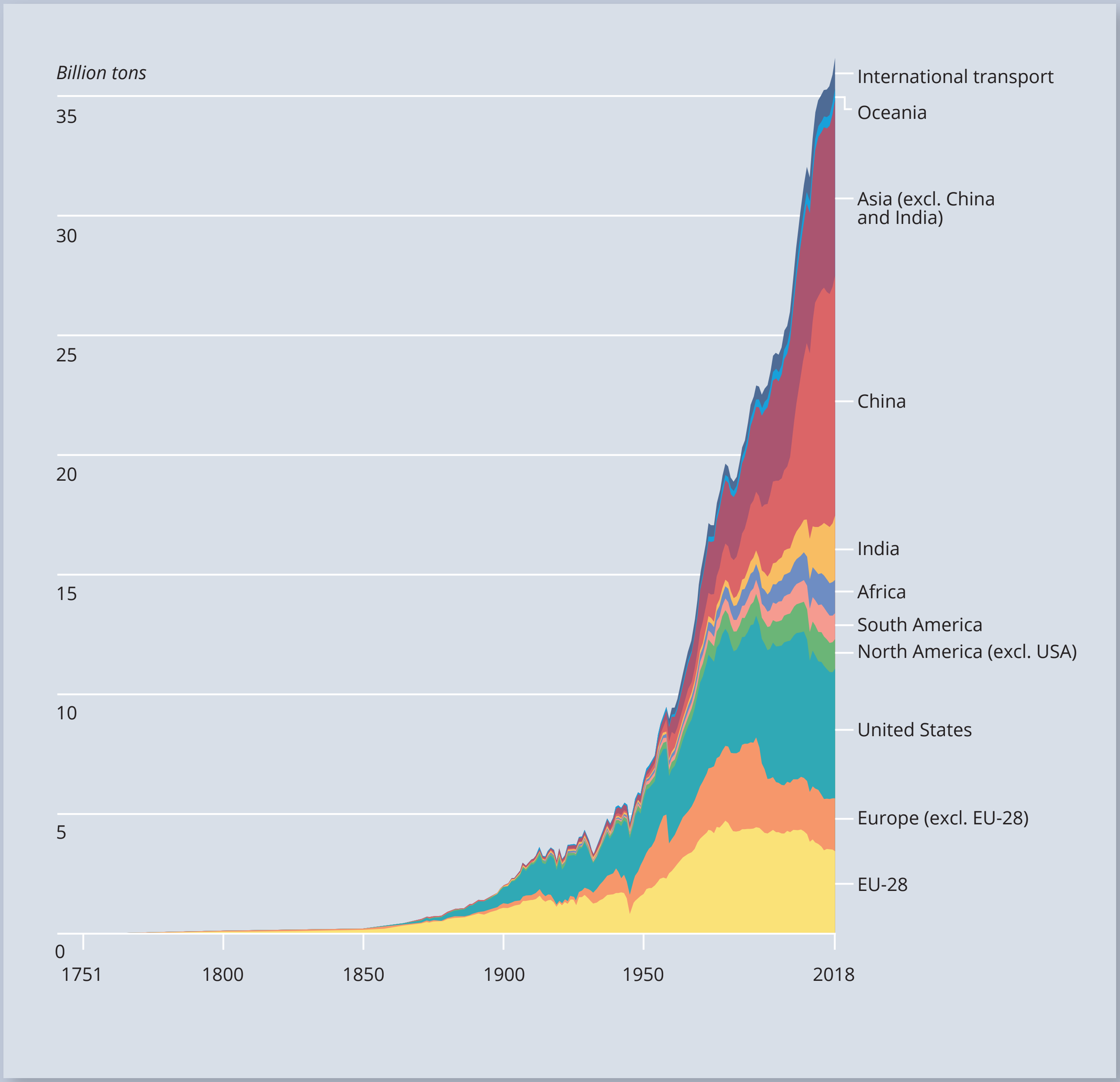
As climate modeling improves, divisions are likely to become more pronounced between those who advocate reaching net zero emissions over decades by transitioning to new technologies and those who argue that net zero must be achieved more quickly to prevent the worst outcomes. State pledges factor in advancements in technologies to mitigate emissions while boosting economic growth and assume that the worst effects of climate change can be avoided through a more gradual approach. Advocates of faster action argue that the window to avoid the cataclysmic effects is closing and that more dramatic, immediate behavioral changes are required. Limiting the global temperature increase to 1.5°C will require unprecedented changes in energy consumption and production to allow developing countries to grow their economies while not offsetting the carbon reductions from developed countries.

Energy Transition Underway

A critical aspect of the global debate and the ability to mitigate climate change is the speed of the transition from fossil fuels to renewable energy. Even though fossil fuels will continue to supply the majority of energy needs during the next 20 years, wind and solar are almost certain to grow faster than any other energy source because of technological advances and falling costs, and nuclear power production may grow, particularly if new, safer designs emerge. Increasing energy efficiencies probably will also reduce the rate of energy demand growth and the carbon intensity per unit of energy used. A range of current and future technological developments—as well as regulatory and investment choices by governments,

ANNUAL TOTAL CO_2 EMISSIONS, BY REGION

This chart shows CO_2 emissions from fossil fuels and cement production only—land use change is not included.



Source: Carbon Dioxide Information Analysis Center (CDIAC); Global Carbon Project (GCP).
Note: 'Statistical differences' included in the GCP dataset is not included here.
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

KEY EMERGING ENERGY TECHNOLOGIES

The cost to build and operate new **solar photovoltaic and wind-powered plants** is broadly cheaper than equivalent fossil fuel–fired power plants. Even more efficient, lower cost renewable technologies, such as perovskite solar cells, are poised to transform and disrupt energy industries in the next two decades. Moreover, increasingly connected wind turbine technology is enabling massive and lower-cost offshore wind projects worldwide. China is the world's largest producer and exporter of solar panels and wind turbines.

Advanced energy storage will be needed to enable more renewables in grid systems and support broad deployment of electric vehicles. Lithium-ion batteries have seen large cost reduction and performance improvements in recent years, and investments are also increasing in potentially safer, cheaper, more powerful, and longer duration alternatives. In the future, it is likely that advanced energy storage would allow for the development of decentralized and autonomous electrical grids that integrate batteries, renewable power sources, and electric vehicles and that potentially have no need for backup from fossil fuels.

Green hydrogen—produced through electrolysis with no by-products—has the potential to play a greater role in storing excess solar and wind energy and helping to decarbonize heating, industry, and heavy transport. The industry is still in its infancy, but costs are expected to come down because countries with cheap renewable energy sources are particularly interested in it, such as Chile.

Several companies are developing **small modular nuclear reactors (SMRs)**, about one-third the size of traditional nuclear reactors, which could lead to broader acceptance from countries traditionally opposed to nuclear projects because SMRs are smaller and safer. SMRs have the potential to provide power generation to remote areas, such as in Africa, which could help developing countries electrify their populations without increasing emissions. In addition, SMRs—when combined with solar and wind power—could help solve the problem of intermittency.

businesses, and consumers—will influence energy use in buildings, transportation, and power, which together account for a majority of global emissions. Many of these technologies could also contribute to greater energy resilience and self-sufficiency for states.

Increased Efforts To Remove Carbon Dioxide

The success of efforts to remove carbon dioxide from the atmosphere will also be critical. The Intergovernmental Panel on Climate Change estimates that mitigating emissions alone almost certainly will not be enough to limit warming to 1.5°C, which increases the importance of technologies that remove carbon dioxide from the atmosphere to use it or store it underground. Most of the modeled pathways to limit warming to 1.5°C involve a substantial expansion of carbon dioxide removal (CDR) primarily through afforestation and bioenergy with carbon capture and storage (BECCS). Other technologies being researched include soil sequestration, ocean fertilization, and direct air capture. Research into and a push to deploy BECCS—still a nascent technology—almost certainly will increase because it is one of the few negative emissions technologies that exist because it uses carbon dioxide to grow biomass that is converted to usable energy while storing the carbon dioxide underground. Currently about 25 commercially operational CDR projects offset a negligible amount of yearly emissions, and efforts to scale up CDR will face policy, technological, and economic constraints absent market incentives. More countries may introduce a carbon tax, or a credit for removing carbon, in an effort to speed up CDR as well as broaden adoption of renewable energy technologies.

Complementary Actions on Emissions

Many more actors are likely to join international and governmental efforts to address climate and environmental challenges. Action at the local level has already increased, and a growing number of companies have pledged to go carbon neutral. Some large asset managers have concluded that climate change threatens their long-term returns and are requiring carbon emissions disclosures from firms in their portfolios or declining to invest in some fossil fuel projects. In 2018, nearly 10,000 cities and municipalities in 128 countries took some form of climate action, as did 6,225 companies headquartered in 120 countries, representing $36.5 trillion in revenue, larger than the combined gross domestic product (GDP) of the United States and China. Public-private partnerships are becoming a preferred operating framework, partly a recognition that nonstate efforts are most effective when linked to state action.

GROWTH OF RESILIENCE AND ADAPTATION

In addition to efforts to reach net zero emissions, many countries and local communities will expand investment in adaptive infrastructure and resilience measures. Some measures are as inexpensive and simple as restoring mangrove forests or increasing rainwater storage; others are as complex as building massive sea walls and planning for the relocation of large populations. A key challenge for these efforts will be funding for vulnerable communities—particularly as governments face competing fiscal and political challenges and have to choose which communities to support.

Public-private partnerships are innovating new insurance approaches aimed at building resilience to climate risks, such as insuring natural assets like the Mesoamerican reef off Mexico or index-based weather insurance for local farmers in Kenya. These approaches rely on new data and machine learning technologies—suggesting that as these technologies advance during the next 20 years, resilience mechanisms may become more sophisticated.

Calls for Geoengineering

As warming gets closer to exceeding the Paris Agreement goals, it is increasingly likely that states and nonstate actors will more aggressively research, test, and possibly deploy geoengineering measures—deliberate large-scale interventions in the earth's natural systems—to try to counteract climate change. Current research is largely focused on solar radiation management (SRM), an effort to cool the planet by reflecting the suns energy back into space. Stratospheric aerosol injection (SAI), a form of SRM that sprays particles in the stratosphere to cause global dimming, has attracted funding by those who fear the worst of climate change. Proponents argue that the needed energy transformation will happen too slowly and that SAI can buy the planet time because it is technologically feasible and less expensive than mitigation.

Current research is almost entirely in computer models with academia, nongovernmental organizations, and private companies playing a leading role. However, there will be increased calls for countries to begin engaging in the dialogue and possibly take leadership to develop international agreements that could help set research standards, ensure transparency in live tests, determine the legal framework around if, how, and when to deploy SRM technologies, and monitor the effects. The possibly catastrophic unintended side effects are not well understood, and some scientists fear that SRM, while keeping temperatures down, would create unexpected and devastating changes in weather systems and rainfall patterns. Countries and nonstate actors deploying it alone will increase the risk of conflict and blowback, especially when others blame them for a disaster they believe was caused by geoengineering.

BROADER IMPLICATIONS AND DISRUPTIONS

In addition to direct physical effects of climate change, states and societies are likely to be strained by hard choices and tradeoffs given the difficulty and costs of drastic emissions cuts and adaptive measures. The burden of these steps will not be evenly distributed within or between states, and the long-term payoff of mitigation policies runs counter to political incentives, making it difficult to sustain controversial commitments. The second- and third-order implications of climate change will affect human and national security in several ways.

Drive Societal Cleavages and Political Movements. Concerns about climate change have grown across the globe with hundreds of thousands of protesters—mostly young people—marching in the streets advocating for faster change. Policy responses to mitigate or adapt to climate change also contribute to political volatility—particularly when they are linked to broader socio-political interests—such as the French protests against fuel price hikes in 2018. In Europe, nationalist and populist parties have capitalized on public concerns about the economic hardships associated with climate mitigation policies, and they have framed their opposition in terms of equality and social justice for working class populations.

Increased Pressure for Global Action. As warming continues to rise, there will be more debate and tension among countries over transparency, cuts, and responsibility. Developing countries that want the room to grow their economies and increase emissions will more forcefully demand that developed countries provide them with advanced energy technologies to leapfrog their energy systems to a low carbon model. In addition, developing countries will increasingly demand that developed countries meet their commitments to provide financing to help vulnerable populations adapt. Greater demands will be made on international financing vehicles such as the Green Climate Fund, which has approved $4 billion worth of adaptation projects.

Heighten Competition. Climate change and environmental degradation will contribute to and reflect a more contested geopolitical environment. Countries and other actors are likely to compete over food, mineral, water, and energy sources made more accessible, more valuable, or scarcer. Receding Arctic sea ice is opening new sea routes and opportunities to access valuable resources there, including natural gas and oil deposits, rare earth metals, and fish stocks. Russia is building more icebreakers to patrol its northern coastline and project power as an Arctic leader, and even non-coastal states like China and India are seeking to take advantage of shorter trade routes and resources. In addition, China is trying to boost its international image by claiming to be a leader on climate diplomacy despite its growing emissions—already the highest in the world.

Contribute to Instability and Conflict Risk. Rarely is climate change the sole or even primary driver of instability and conflict; however, certain socio-political and economic contexts are more vulnerable to climate sparks that ignite conflict. Countries of particular concern are those with ethnic or religious polarization; livelihoods highly dependent on natural resources or agriculture; weak or illegitimate conflict resolution mechanisms; a history of violence; and low adaptive capacity. For example, an increase in drought or extreme weather may reduce the opportunity cost of joining armed groups for struggling farmers and herders, while sectarian elites may advance their polarizing political goals by exploiting local grievances exacerbated by climate change.

Strain Military Readiness. While militaries will continue to adapt and fight in the changing world, climate effects will strain readiness and compound fiscal pressures on many militaries. Storm surges and sea level rise will force changes to the design and protection of naval bases and aircraft runways, prolonged extreme heat will limit training days, and major storms and floods will force militaries to divert more resources to disaster relief at home and abroad.

Increase Pressure on Strained International Systems. Current international law and cooperative bodies are increasingly mismatched to global climate challenges. For example, international refugee law does not account for people displaced by climate change effects. Many existing organizations designed to help manage shared resources, such as the Arctic Council or the Nile Basin Initiative, may be overwhelmed or sidelined, given their voluntary nature and lack of enforcement mechanisms. Also, efforts to develop international standards or regulations for high-risk activities like SRM lag behind the technology, increasing the possibility that countries or individuals will pursue unilateral action that risk blowback.

ENERGY TRANSITION GEOPOLITICS AND ECONOMICS

The transition from fossil fuels has the potential to significantly reshape geopolitics and economics, depending on its speed and structure. Petro-states—currently accounting for 8 percent of world GDP and nearly 900 million citizens—would face major revenue losses in an aggressively decarbonizing scenario. Those that can more efficiently and cheaply extract oil or diversify their economies will better weather the transition.

In addition, the transition will diminish countries' ability to use energy as a tool of coercion or statecraft because energy systems will become more decentralized. Countries will have decreased leverage in energy markets because oil and renewables operate differently; the former is an extracted resource that is traded, whereas the latter is harnessed by building out domestic infrastructure. As a result, it will be more difficult for any one country to affect others' energy supply. For example, Chinese dominance of the clean energy equipment market does not allow Beijing to threaten global energy supplies in the way that control of the oil markets by the Organization of Petroleum Exporting Countries once did.

However, a shift to renewable energy will increase competition over certain minerals, particularly cobalt and lithium for batteries and rare earths for magnets in electric motors and generators. As actors race to develop new renewable energy technology during the next two decades, they will focus on countries that supply these minerals, such as the Democratic Republic of the Congo and Bolivia.

Photo / Bigstock