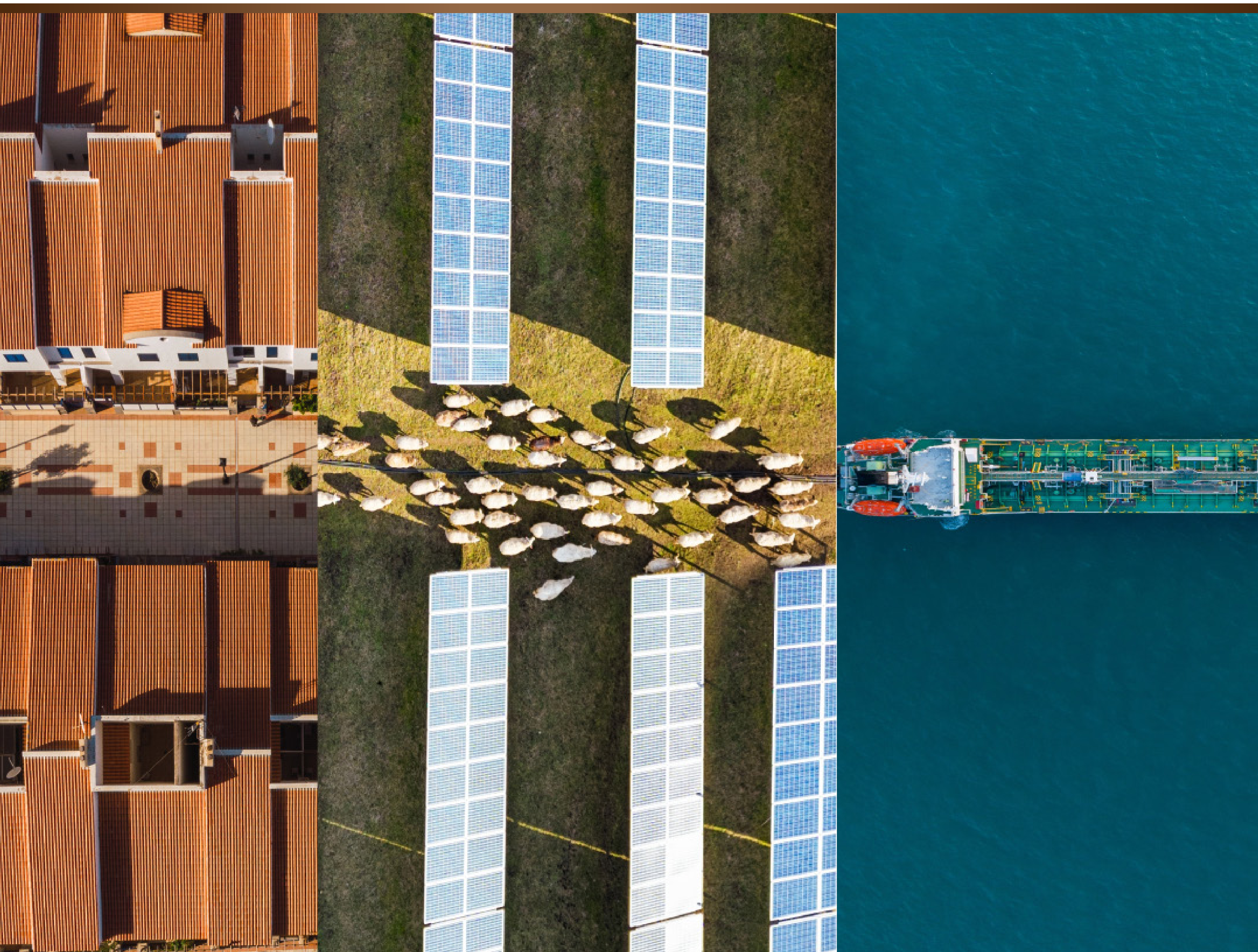
J.P.Morgan

NAVIGATING THE NEW CLIMATE ERA:
BUILDING INTUITION FOR STRATEGIC DECISION-MAKING

Introduction to Climate Intuition



FOREWORD

Creating and distributing high quality content is one of the many ways we actively engage with our clients and other stakeholders. We do this on a daily basis through a variety of channels and help our clients sift through a fast-changing world. Consistent with this aspiration to have deep expertise on topics of interest to our clients, we were pleased to welcome back Dr. Sarah Kapnick late last year to J.P. Morgan after a twenty-seven-month stint as the Chief Scientist at the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). Sarah is an established leader in climate science who now serves as the Global Head of Climate Advisory at J.P. Morgan. Before joining NOAA, Sarah was a Senior Climate Scientist and Sustainability Strategist for J.P. Morgan's Asset & Wealth Management division, where she produced thought leadership on climate and environmental issues, counseled on new business and risks, and advised clients. Through her career, Sarah has toggled between roles within scientific organizations and financial services and brings in a unique ability to apply a commercial and pragmatic lens to scientific issues.

As a global bank, one of our key roles in the economy is to help identify and price financial risk. This is an important step in facilitating capital formation which helps drive the economy forward. Climate change poses an emerging global risk, which can manifest as hurricanes, floods, wildfires, droughts, heatwaves, etc. and their impacts. In today's rapidly evolving world, understanding climate risk is important for staying ahead in the financial landscape. We believe we have a role to play in helping market participants understand and incorporate the financial impacts of this risk in asset prices. Sarah's expertise on issues related to climate, energy transition, nature and biodiversity will help us better inform our clients and enhance our firm's climate thought leadership. In addition to advising clients on a bilateral basis, Sarah will also periodically write on topics related to climate and energy transition under the banner of "Climate Intuition".

We are pleased to introduce Sarah and the first edition of Climate Intuition here. This first edition will lay the groundwork for why climate risk is an increasingly relevant consideration for capital providers, capital seekers, and policy makers. In future editions of Climate Intuition, Sarah will plan to dive into different facets of climate risk and discuss potential solutions for businesses to combat those risks. We hope you will find this series instructive. Please don't hesitate to reach out to Sarah or your J.P. Morgan contact if you would like to discuss this more.

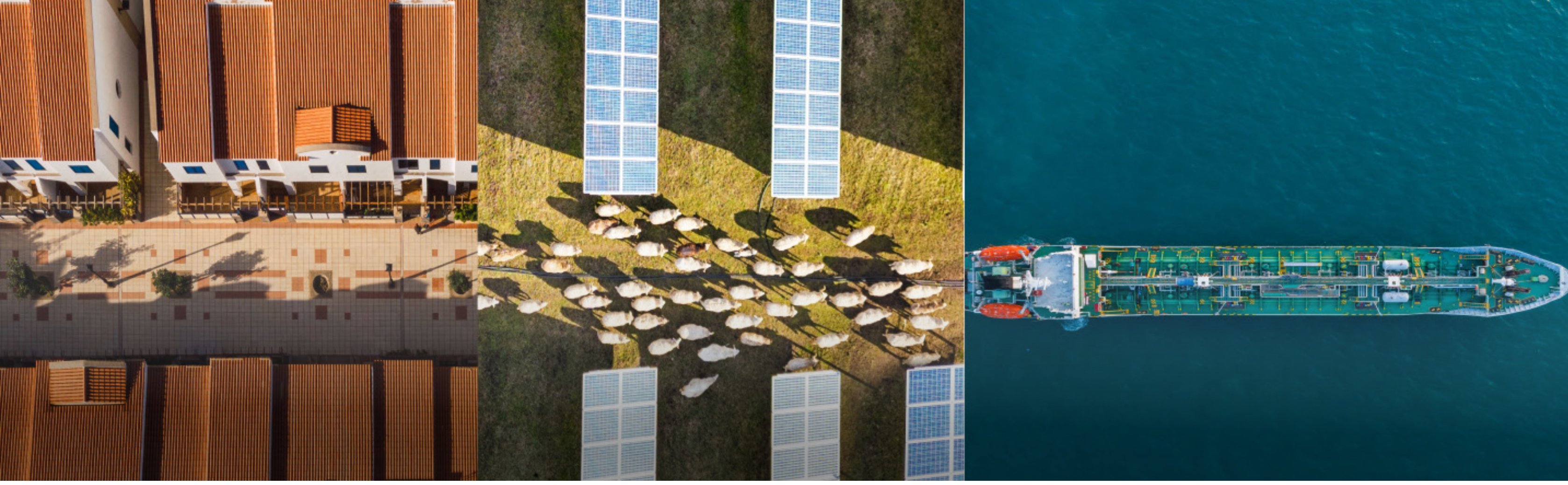
Regards,

Ashley Bacon

Chief Risk Officer, JPMorganChase

Rama Variankaval

Global Head of Corporate Advisory, Commercial & Investment Bank, J.P. Morgan



Executive Summary

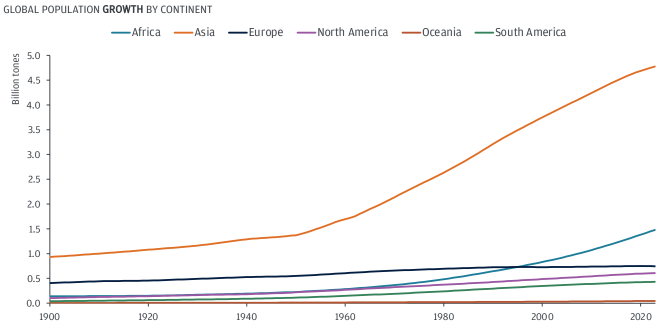
This thought leadership series aims to build **climate intuition**—to understand future probabilities and ask smarter questions about climate issues, where technology or demand for solutions may evolve, and how policy and geopolitics can lead to a variety of financial outcomes. To develop a more nuanced and proactive approach to climate change.

In my career I have been a serious scientist: conducting research, providing operational seasonal forecasts, and overseeing the science and technology program and policy of a $6bn federal U.S. agency. But I've also spent time on the buy and sell sides and advised on matters of commerce, diplomacy, and national security. This diverse experience allows me to bridge the gap between scientific understanding and practical application, fostering informed decision-making in the face of climate challenges.

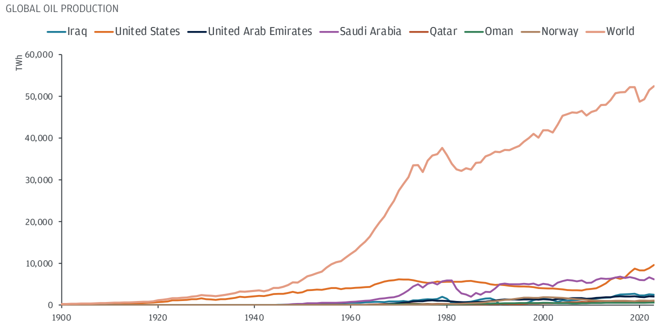
Climate change is a challenge for the economy. Stricter emissions regulations may increase compliance costs, but can also drive new technology innovation over time. Extreme weather can damage infrastructure and stop production, lead to costly repairs and insurance claims, and affect supply chains. Resource competition for water and farmland can increase prices. Shifts in consumer preference for climate-friendly products can affect market share. Success in the New Climate Era hinges on our ability to integrate climate considerations into daily decision-making. Those who adapt will lead, while others risk falling behind.

Macroeconomic trends & emergent climate thinking

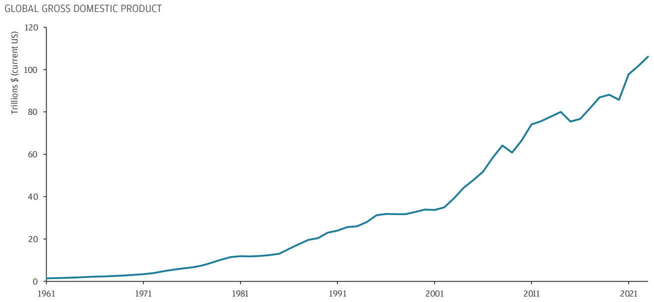
Population growth, fossil fuel production, and agricultural productivity have persistently risen over the last century, enabled by technological advancements. Macroeconomic and big-picture investment themes often rely on these metrics to project further growth and potential for limits. However, in climate, these metrics interact, historically contributing to the persistent rise in greenhouse gas emissions and their accumulation in the atmosphere.



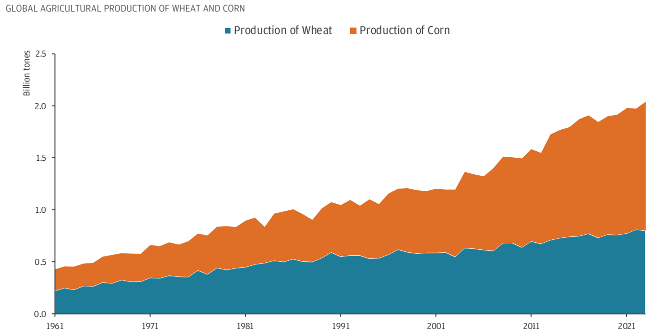
Source: HYDE (2023); Gapminder (2022); UN WPP (2024)



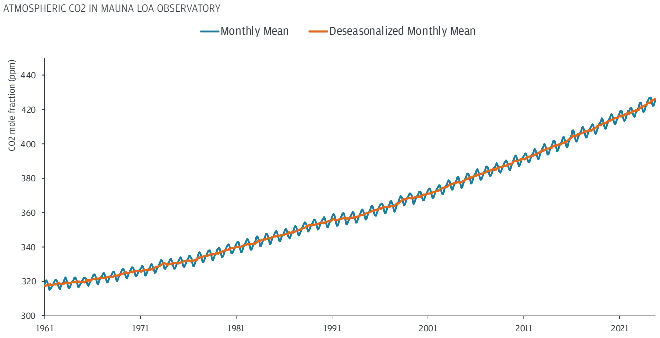
Source: Energy Institute - Statistical Review of World Energy (2024); The Shift Data Portal (2019)



Source: World Development Indicators



Source: Food and Agriculture Organization of the United Nations. 2025



Source: NOAA

Figure 1: Metrics for Modeling the Future. (a) world population by region, (b) global oil production, (c) gross domestic product, (d) agricultural productivity, (e) carbon dioxide (CO2) concentrations in the atmosphere.

Climate change will increasingly manifest with each additional ton of carbon dioxide emitted. These manifestations will be in physical changes in weather extremes and climate, biological changes in loss of species diversity or degradation of nature, and chemical changes as carbon dioxide absorption makes rivers, lakes, and the ocean acidic. These will have economic and societal costs.

Here is the concluding assumption of national security[1,2] and climate experts: as societal dissatisfaction with negative outcomes grows, responses are inevitable. The financial, social, and ecological effects of climate change will be unevenly distributed across industries, countries, and communities. Such inequalities, or even the **perception** of present or growing future inequalities can fuel social unrest and conflict.[3,4]

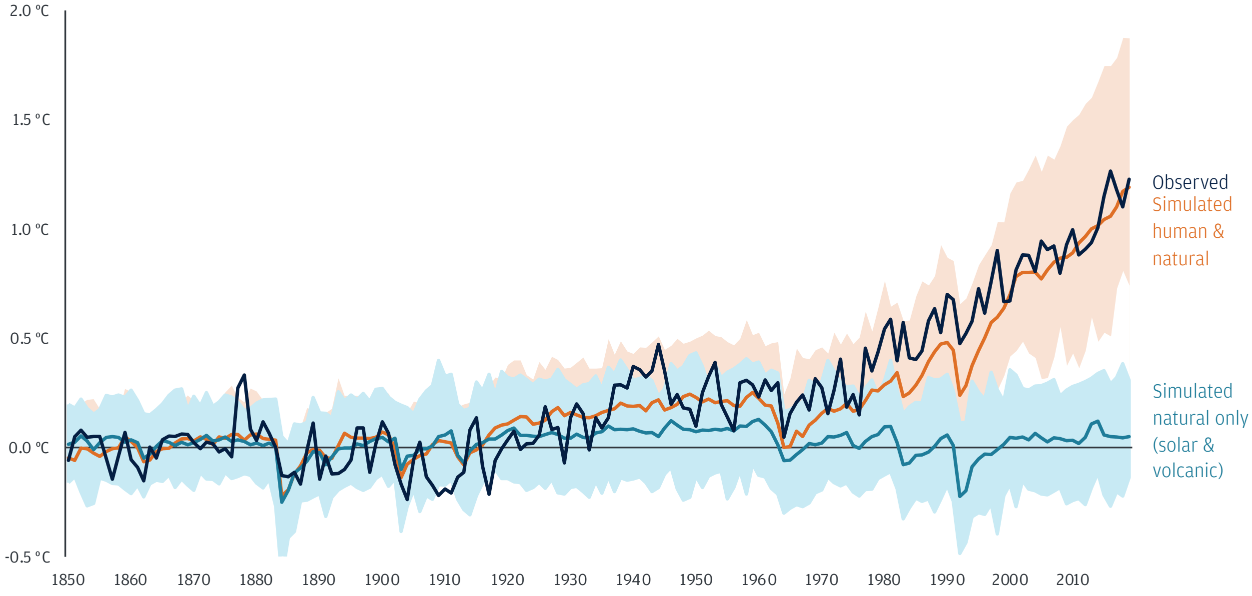
Societal responses to climate change should be expected, but will not be uniform nor monotonic. The 2015 United Nations Paris Agreement set a goal of global temperatures remaining well below 2C and to pursue efforts to limit temperature increase even further to 1.5C.[5] Climate Technology sector innovation and investment has been growing over the last decade.[6] Corporate net zero plans have been adopted and legislation has been passed, but these have also been reversed with changes in leadership, economic conditions, and technological feasibility stagnation. Current country policies, when taken together, are projected to result in about 2.7C of warming.[7]

Takeaway: Predicting the future using climate metrics requires quantifying how the climate changes and their interactions across society. This analysis can help identify a set of outcomes for how investments, technology, and policy will respond and pragmatically build the solutions towards optimization for a combination of outcomes, especially when there is uncertainty from the human response to climate change. It may even require looking at traditional macroeconomic metrics through a new climate-adjusted lens as climate change and societal responses influence the economy.

We are in a new climate era

One of the simplest measures of climate change is annual global temperatures. Observed temperatures were long within a steady range over time. But only in the last 1-2 decades does that range of temperature observed fall well outside that historic range (black line versus shading in figure below). Climate model simulations help explain where these climate paths have diverged (red vs. blue shading below), and are used to quantify present and future risks.

CHANGE IN GLOBAL SURFACE TEMPERATURE (ANNUAL AVERAGE) AS OBSERVED AND SIMULATED USING HUMAN & NATURAL AND ONLY NATURAL FACTORS (BOTH 1850-2020)

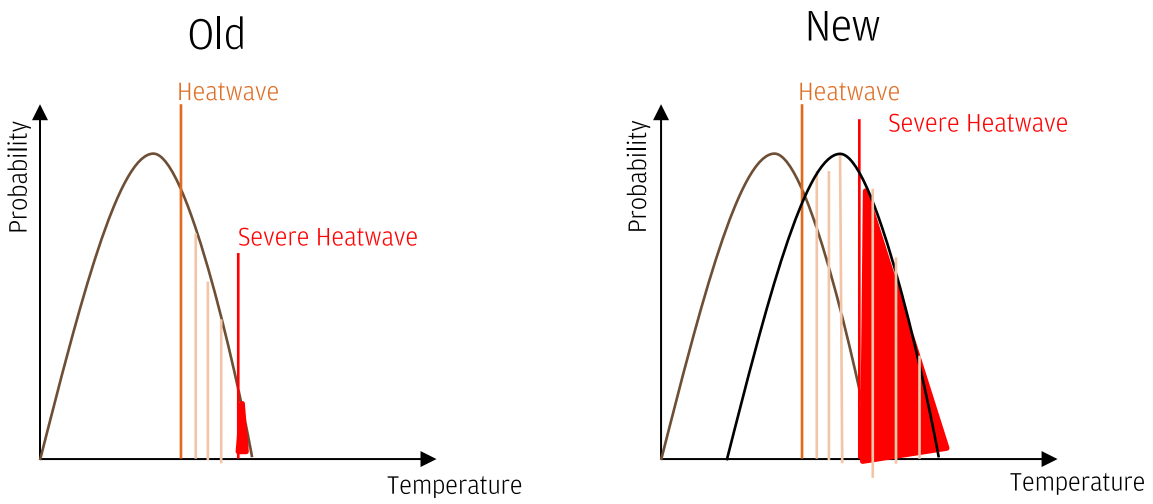


Source: Figure SPM.1 in IPCC, 2021: Summary for Policymakers

Figure 2: Change in annual global surface temperatures: observed and simulated (with and without human influences) from 1850-2020. Adapted from IPCC, 2023: Summary for Policymakers doi: 10.59327/IPCC/AR6-9789291691647.001.

Everything optimized for historic climate of the 20th century faces increasingly different conditions. For example: roads in the Pacific Northwest of the U.S. buckled under the 2021 heatwave as they were not built to withstand previously unrealized temperatures.[8] In 2024, flooding associated with exceptionally heavy rainfall in Central Europe rapidly overwhelmed water management infrastructure designed and upgraded for previous high water marks.[9] The impacts of climate change will be determined by the reliance of human systems on a historic climate, divergence from previous conditions, and adaptative actions to minimize damages.

While average global temperature change may appear linear over time (one can draw a line to show the rate of change), other statistics like wildfire and heatwaves respond in non-linear ways (one can draw a swoosh) either due to climate math or human behavior. For example, the likelihood for the most extreme heat waves has been growing at a more rapid pace than changes in lesser heatwaves and average temperatures. This isn't due to unrealistic forecasts of future climate, but is a simple mathematical fact of how shifting distributions affect probabilities of extreme events and our perception of risk above a specific threshold.[10] In other words, while average temperatures inch up steadily, extreme events like heatwaves are happening at a faster pace.



(a) Area under curve provides the likelihood of a heatwave or severe heatwave.

(b) Area under new curve provides the likelihood of a heatwave or severe heatwave in a warmer climate (shifted to right). Size of New/Old areas is greater for severe heatwaves.

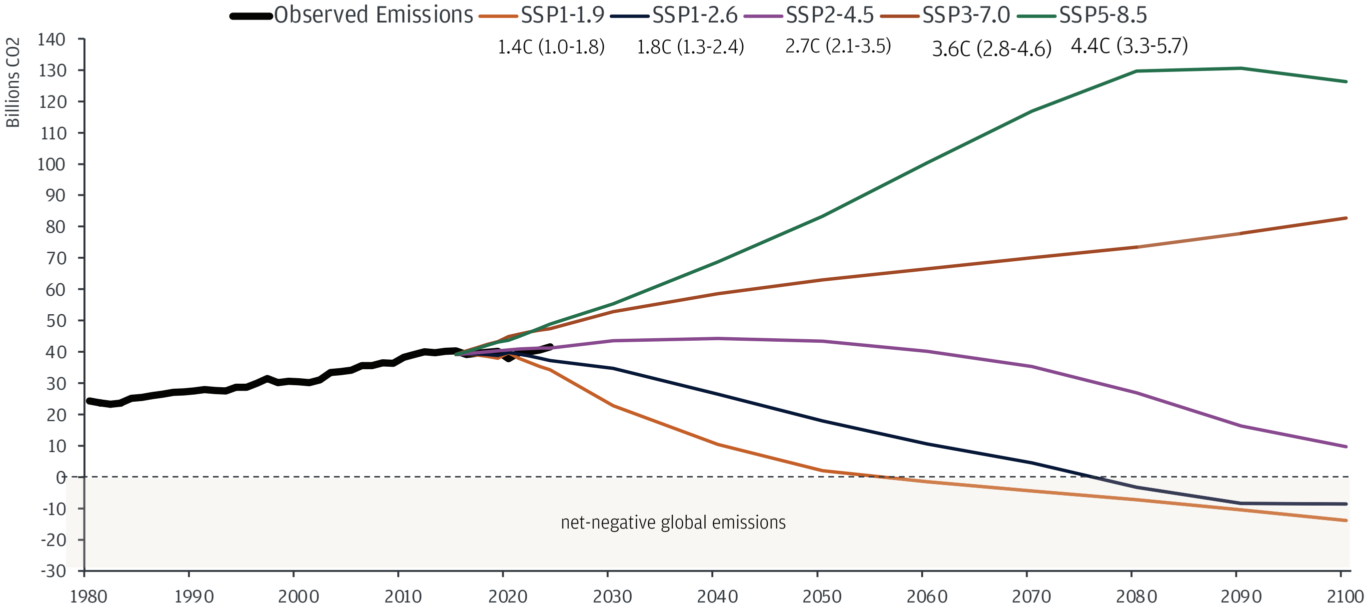
Figure 3: Climate math schematic showing more extreme events can happen faster than less extreme events. As the distribution function shifts warmer (left to right), the likelihood of heatwaves and severe heatwaves increases (area under curves above a "heatwave" or "severe heatwave" threshold). The ratio of the area under these curves provides a factor of change: how much the probability changes (areas of New/Old) for a given color. Larger values for New/Old mean a more rapid jump in frequency. Adapted from Patel, Ronak N., David B. Bonan, and Tapio Schneider. "Changes in the frequency of observed temperature extremes largely driven by a distribution shift." Geophysical Research Letters 51, no. 24 (2024): e2024GL110707.

Takeaway: Continuing with static thinking based on experience alone, will make it difficult to identify emerging climate risks and accurately price them in and will make it harder to identify opportunities to lead in response to these risks. Especially as extreme weather and climate events amplify in probability and magnitude.

Taking stock of where we are and where we are headed: emissions

Greenhouse gases are accumulating in the atmosphere from human activities. In 2024, estimated total global carbon dioxide emissions reached an all-time high of 41.6 billion tons. Right now, global carbon dioxide concentrations have been following middle-of-the-road projections, tracking pathways to more than 2C of warming.[11] Note: these emissions pathways do not have probabilities assigned to them, they are simply scenarios of different emissions and therefore warming trajectories.

Observed vs. Projected Emissions

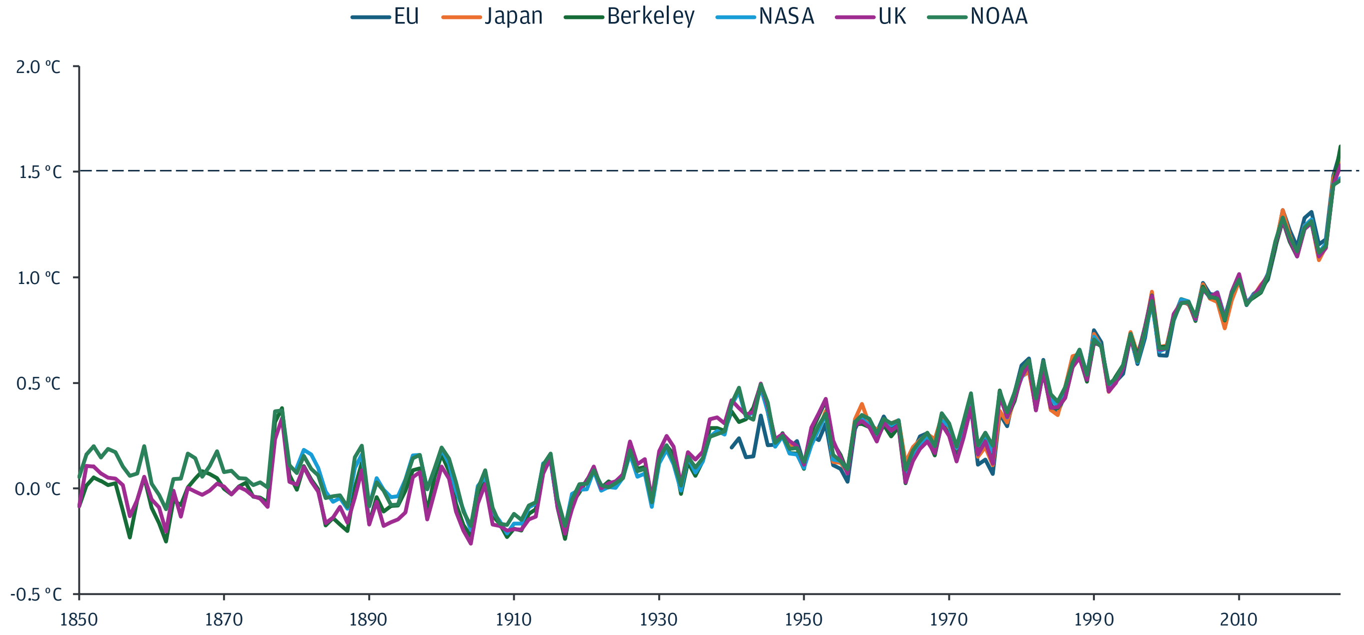


Source: Global Carbon Budget (2024) and Figure SPM.4 in IPCC, 2021: Summary for Policymakers

Figure 4: Observed and projected global emissions. Projection scenarios start in 2015 and are given as Shared Socioeconomic Pathways (SSP) representing a collection of future population growth, economic development, and land use. These were developed for the 2021 Intergovernmental Panel on Climate Change (IPCC) Assessment Report Version 6 (AR6). Average temperatures and ranges based on climate model simulations for each SSP scenario are provided in the legend.

At the same time that greenhouse gas emissions reached a new high, 2024 was the hottest year on record. In the majority of temperature data sets (EU, Japan, Berkeley, UK), temperatures exceeded 1.5C of warming for the first time in a calendar year versus pre-industrial levels (taken as a 1850-1900 reference period).[12] NASA and NOAA products fell just below 1.5C of warming.[13] Temperatures in 2025 are predicted to cool under most seasonal predictions[14] as the latest El Niño dissipated into a weak La Niña[15].

GLOBAL AVERAGE TEMPERATURE



Source: ERA5 (C3S/ECMWF), JRA-3Q (JMA), GISTEMPv4 (NASA), HadCRUT5 (Met Office Hadley Centre), NOAAGlobalTempv6 (NOAA) and Berkeley Earth

Figure 5: Average global temperature observed from 1850 to present. Measured by various data sets (EU ERA5, Japan JRA, NASA GISTEMP, UK HadCRUT5, NOAA, Berkeley Earth). All data sets use similar observations, but different methodologies, especially pre-1900 to recombing historic data into global temperatures. Data as of January 15, 2025. [16]

While the outlook for 2025 is cooler, as long as greenhouse gases accumulate in the atmosphere, global temperatures will increase on average over multiple years and records will continue to break. As temperatures rise, they bring the world closer to surpassing the temperature threshold declared in the 2015 Paris Agreement.

Takeaway: Global emissions are still growing following scenarios to temperatures above 2C, not declining. A 1.5C global temperature milestone has been reached. A linear trendline from 1950 projects global temperatures above 1.5C by 2040s.

When are we in a 1.5C world? Definitions are key. But the human response is unclear.

The Paris Agreement did not clearly define how global temperature should be measured. As a result, it and the passing of a 1.5C threshold can be interpreted several ways.

Definition	Explanation	Approximate Passage date
• (1) January to December Average	• When a calendar year exceeds 1.5C	• 2024
• (2) Probability of 1.5C is more than 1.49C for a given set of years	• 1.5C+ happens in a row or in a collection of years more often than not	• 47% chance 2024-2028 average will exceed 1.5C according to World Meteorological Organization • 50% chance reaching by 2030 according to Global Carbon Project • Extrapolation of observed trends since 1950: by 2040s
• (3) 20-30 Year Average	• Requires consistent decade+ over 1.5C Depends on emissions pathway	• Last half of century
• (4) 1.5C in 2100 after "overshoot"	• Emissions scenarios theorized to exceed and return to 1.5C by 2100 by IPCC CMIP6 • Requires carbon dioxide removal or other climate intervention technologies to achieve • Note: overshoot is not without costs as some aspects of the Earth System do not return with temperature decline, especially biological, ocean, and glaciers	• Passage and return date to 1.5C varies by scenario

Table 1: Definitions for calculating a 1.5C average global temperature and approximate passage date. Significant uncertainty in passage dates due to uncertainty of warming from non-CO2 agents (methane, nitrous oxide, aerosols) and natural variability in climate system (volcanic eruptions). Passage dates from Copernicus, 2024 Global Carbon Project Report, World Meteorological Organization, and IPCC Special Report on Global Warming of 1.5C.

The general definition of practice is to use the 3rd definition: 20-30 year average temperature. This is due to natural variability in climate causing multi-year or multi-decade departures due to volcanoes and fluctuations in ocean currents. A multi-decade average smooths out these "natural" fluctuations. The World Meteorological Organization recently spelled out definition #3 as reaching 1.5C "over decades" as the benchmark for the Paris Agreement when predicting temperatures over the next decade.[17]

However, reaching 1.5C in definitions 1 and 2 are necessary prerequisites for achieving 1.5C at definition 3. Psychologically, passing these milestones increases the sense of urgency for people wanting to manage temperature to below 1.5C under definition 3.

To complicate matters, emissions scenarios developed for 1.5C global temperatures allow for a 4th definition where "overshoot" occurs. This allows temperatures to rise above 1.5C, but then lower below the threshold through carbon dioxide removal by the end of the century.[18]

Further emissions management for 1.5C by 2100 therefore either requires:

1. Emissions reductions
2. Scaling up of carbon dioxide removal (engineered and nature-based like reforestation) with emissions reductions made less dramatic than on their own

The largest decline in a single year (7% of total[19]) happened in 2020 due to COVID-19 lockdowns. To avoid definition #2's strictest timeline, a rate of 7% reductions a year does not get us to net zero in 6 years. There is obviously more time for definitions 3, and 4, but they are still reliant on emissions reductions and in the case of 4, scaling carbon dioxide removal.

Takeaway: Adhering to temperatures below 1.5C will require emissions reductions. Depending on your definition of 1.5C, they may require historic annual reductions and potentially carbon removal. Conversely, if you have a technical or financial view that carbon dioxide removal will not scale, you should assume there is a difficult path to 1.5C (i.e. emissions reductions to zero depending on your definition in 6, 15, or 30+ years). If that is the case, you need to plan for the physical manifestations of climate change and social responses that will ensue if your investment horizons are longer.[20]

Climate Intuition: Where we're going in 2025

While navigating the complexities of climate change, it's imperative to develop your climate intuition. In this series, We will first dive into how climate change is becoming a variable, but predictable cost by looking at insurance markets. In response, we'll explore how adaptative action can be taken to live with present and future climate change. With the new administration in the U.S., we'll explore national security issues of energy independence in a changing climate.

The insights from this thought leadership series will underscore the interconnectedness of economic, technological, policy, and environmental factors, highlighting the urgent need for planning. So you can position yourself to not only mitigate risks but also seize opportunities in this New Climate Era.

FOOTNOTE

[1] The CAN Corporation. “National Security and the Threat of Climate Change,” (2007), 35pp. https://www.cna.org/archive/CNA_Files/pdf/national%20security%20and%20the%20threat%20of%20climate%20change.pdf

[2] https://education.cfr.org/learn/reading/national-security-climate-change

[3] National Academies of Sciences, Engineering, and Medicine. 2023. Climate Security in South Asia: Proceedings of a Workshop. Washington, DC: The National Academies Press. https://doi.org/10.17226/26926.

[4] National Academies of Sciences, Engineering, and Medicine. 2024. Climate Security in Central America: Proceedings of a Workshop. Washington, DC: The National Academies Press. https://doi.org/10.17226/27203.

[5] https://unfccc.int/process-and-meetings/the-paris-agreement

[6] See the recent JPM report on Climate Tech trends: https://www.jpmorgan.com/insights/esg/sustainable-financing/climate-tech-industry-trends

[7] https://climateactiontracker.org/global/temperatures/

[8] https://www.seattletimes.com/seattle-news/weather/pacific-northwests-record-smashing-heat-wave-primes-wildfire-buckles-roads-health-toll-not-yet-known/

[9] https://www.worldweatherattribution.org/climate-change-and-high-exposure-increased-costs-and-disruption-to-lives-and-livelihoods-from-flooding-associated-with-exceptionally-heavy-rainfall-in-central-europe/

[10] Patel, Ronak N., David B. Bonan, and Tapio Schneider. “Changes in the frequency of observed temperature extremes largely driven by a distribution shift.” Geophysical Research Letters 51, no. 24 (2024): e2024GL110707.

[11] Note: emissions were projected out from 2015 even though the report comes out years later. The reason for this is scenarios are developed by scientists with advanced time for modeling centers around the world to create the climate change simulations and analyze them for synthesizing research of future climate. This lag allows us to review how observed emissions have tracked against scenario projections.

[12] https://climate.copernicus.eu/copernicus-2024-first-year-exceed-15degc-above-pre-industrial-level

[13] NASA: https://www.nasa.gov/news-release/temperatures-rising-nasa-confirms-2024-warmest-year-on-record/ NOAA: https://www.noaa.gov/news/2024-was-worlds-warmest-year-on-record

[14] According to analysis from the North American Multi-Model Ensemble, a collection of models across the U.S. and Canada that provide predictions out 9-12 months. These models are also used to predict hurricane seasons, El Niño/La Niña conditions, and winter weather (critical for energy demand forecasts).

[15] Annual temperature records are usually broken in the calendar year after a strong El Niño dissipates. In this case, a 2023-2024 El Niño transitioned into a 2024-2025 La Niña.

[16] https://climate.copernicus.eu/copernicus-2024-first-year-exceed-15degc-above-pre-industrial-level

[17] https://wmo.int/news/media-centre/global-temperature-likely-exceed-15degc-above-pre-industrial-level-temporarily-next-5-years

[18] Allen, Myles, Opha Pauline Dube, William Solecki, Fernando Aragón-Durand, Wolfgang Cramer, Stephen Humphreys, and Mikiko Kainuma. “Special report: Global warming of 1.5 C.” Intergovernmental Panel on Climate Change (IPCC) 27 (2018): 677.

[19] https://www.globalcarbonproject.org/carbonbudget/archive/2020/Germany_LMU_GCB2020.pdf

[20] Converting technologies from theoretical science fiction (e.g. fusion, solar lasers, climate intervention) into deployment could dramatically reduce emissions or reverse climate change, modifying the math to 1.5C. Based on how long it takes to build prototypes, deploy, test, and if successful scale, this pathway is unlikely on anything less than many decades. But given the high risk/reward profile, there is a niche set of academics, entrepreneurs, governments, and investors growing in this space.

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