PGIM
India Mutual Fund

MEGATRENDS

WEATHERING CLIMATE CHANGE

Opportunities and risks in an altered investment landscape

FOREWORD

After 100 centuries of relative stability, our planet's climate is transforming.[1] This climatic change is not a distant forecast of the future – it is verifiably happening now. Indeed, despite the significant uncertainty over the longer horizon, our climate destiny is largely predetermined over the next decade – the typical time frame of most long-term investors.

Ironically, a highly certain climate destiny translates into massive uncertainty for long-term investors looking to navigate the opportunities and challenges unleashed by climate change. This is for a variety of reasons. First, the most definitive forecast of climate change is for more extreme and greater variability in weather outcomes, the precise timing and severity of which are unclear. Second, it is hard to predict when the externalities, tail risks and nonlinear vulnerabilities from climate change will be fully reflected in market prices. Third, the regulatory, governmental and societal response to climate change remains unclear, especially given the polarized political landscape in which climate change discussions are currently being conducted.

Despite these uncertainties, we believe that climate change is one of the most important structural changes for long-term investors. The implications for investors lie as much around innovative and transformative technologies to further the transition to a lower-carbon world as they do around identifying and mitigating hidden vulnerabilities across their portfolio.

To build an actionable climate change investment agenda, we have drawn on the insights of over 45 investment professionals across PGIM's fixed income, equity, real estate, and private debt and alternatives managers; interviewed over 30 leading academics, economists, policymakers, scientists and climate change investors; and conducted a new proprietary survey of 100 global institutional investors to better understand their current investment actions and future aspirations around climate change.[2]

The humanitarian and economic catastrophe unleashed by COVID-19 in 2020 revealed investors' vulnerability to nonlinear risks with unpredictable timing that are not easily accounted for in standard risk modeling. Climate change is the next slow-burning crisis that will radically reshape investors' risks and opportunities over the next decade. Here at PGIM, we believe investors who understand the potential for climate change to disrupt and reshape the global economy, markets and the investment landscape will be best positioned to navigate the coming decades.

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CHAPTER 1

CLIMATE CHANGE IS TODAY'S REALITY

> *Though policymakers, businesses, and activists may disagree on many aspects of climate change, there is one indisputable fact: the air and water on our planet are warming – and this global warming is accelerating.*

CHAPTER 1

CLIMATE CHANGE IS TODAY'S REALITY

Climate change is no longer a hypothetical risk. Though policymakers, businesses, and activists may disagree on many aspects of climate change, there is one indisputable fact: the air and water on our planet are warming – and this global warming is accelerating (Exhibit 1).

Disruptive climate change is already underway

One of the most tangible effects of climate change is already well underway – the surge in extreme weather. If there was a VIX for weather, it would be near all-time highs – and trending higher still. Exhibit 2 illustrates this greater weather volatility in rainfall patterns. That is because warmer air and sea temperatures are catalysts for increasingly volatile weather, spurring both extreme heat and cold in some areas and drought and floods in others.

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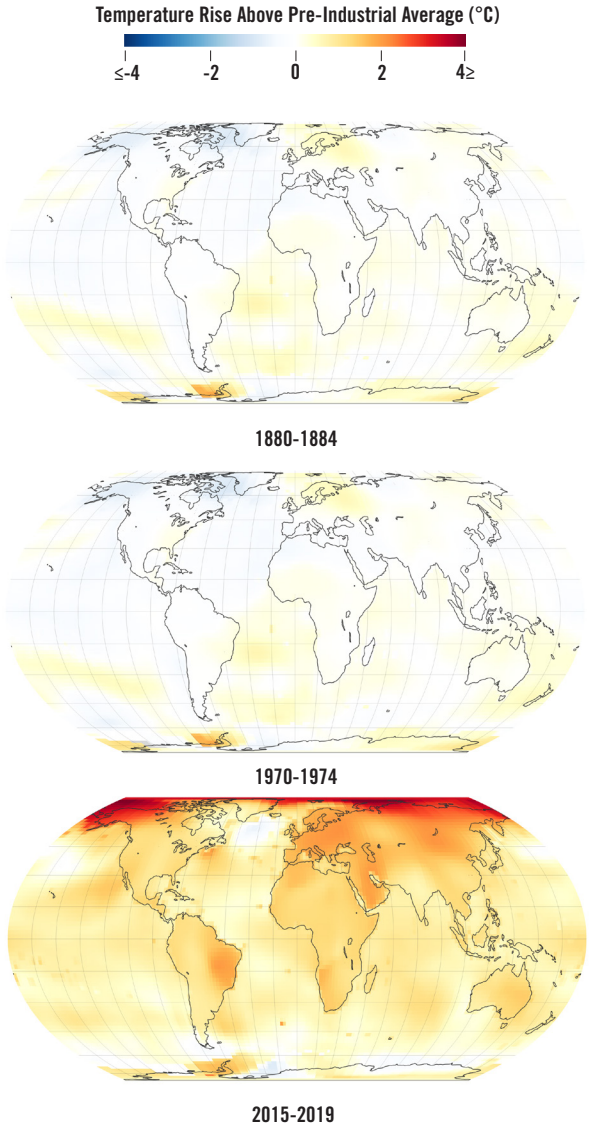
Extreme temperatures

Climate change has led to a rise in extreme heat waves.[i] In India, one of the countries hit hardest, the number of officially recorded heat waves reached 484 in 2018, more than 10 times the number during the entire decade of the 1970s (Exhibit 3).[3] Similarly, Africa experienced 24 extreme heat waves annually in the period between 2006 and 2015 – double the pace for the 25-year period preceding it.[4] Even in the Siberian Arctic, a heat wave in June 2020 saw summer temperatures break 100° F (38° C) for the first time in recorded history.[5]

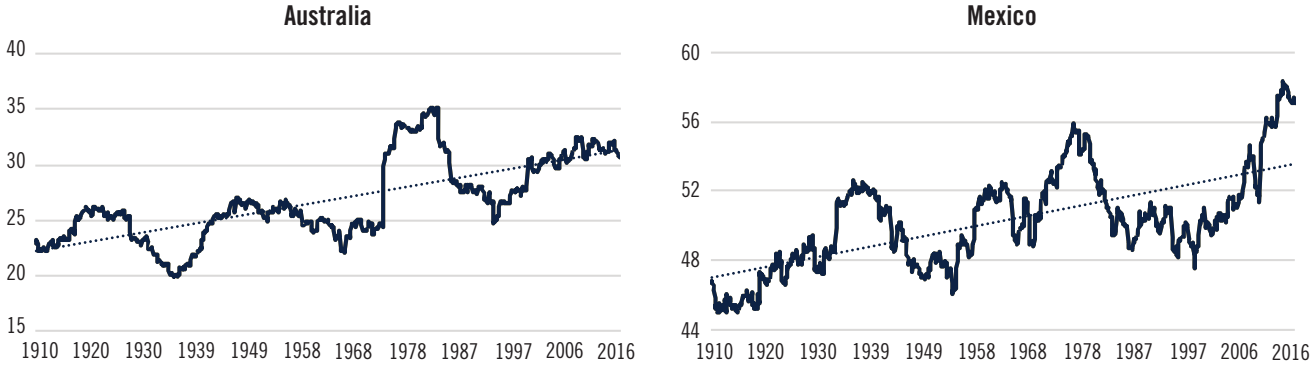
Exhibit 1: **Global Mean Temperature Has Been Rising Since 1880**



Source: "World of Change: Global Temperatures," Earth Observatory, NASA, accessed 2020.

i The rise in global urbanization has also exacerbated the impact of rising temperatures and episodes of extreme heat. For more information on urbanization, see "The Wealth of Cities" http://www.wealthofcities.com

Exhibit 2: **Too Much and Too Little: Rising Variability in Rainfall**
10-Year Rolling Standard Deviation of Monthly Rainfall (mm)



Source: PGIM analysis; "Climate Change Knowledge Portal," World Bank, accessed 2020.

Somewhat counterintuitively, the warming of the planet also leads to extreme cold spells – particularly across North America, Europe and Central Asia.[6] When there is a sharp contrast between icy arctic temperatures and the rest of the world, the jet stream flows strongly along a predictable west-to-east latitudinal path that traps the polar air in the Arctic. But, as Arctic air temperatures increase, the decline in the temperature differential weakens the jet stream and allows it to meander southward. This brings frigid Arctic air (the polar vortex) to lower latitudes across North America, Northern Europe and Central Asia.[7] One episode in 2019 saw temperatures in Chicago and Minneapolis drop to -46°C (-50°F), causing major disruptions in transportion and other infrastructure.[8]

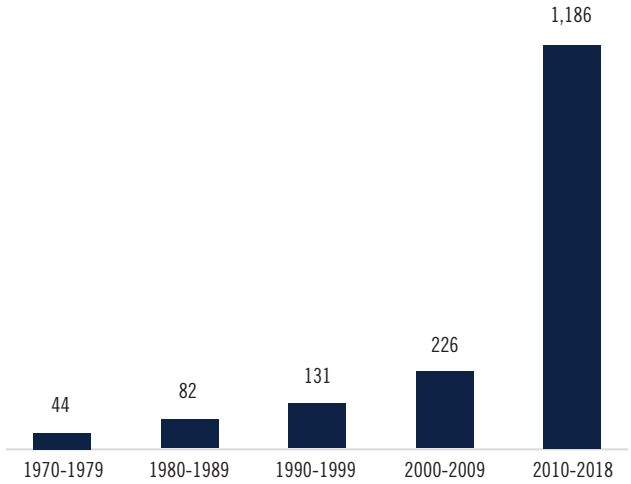
Growing intensity of storms and hurricanes

There is growing evidence global warming is leading to an increase in storm severity. Warming oceans have created higher-intensity hurricanes in the North Atlantic and cyclones in the South Indian oceans, leading to more storms achieving category 3 or higher intensity (Exhibit 4).[9] Indeed, the number of named storms in the Atlantic hit a new record in 2020.[10]

In addition to hurricanes, warming air raises the atmospheric water retention rate which increases the frequency of severe rainfall events.[ii] Estimates suggest that the atmosphere's capacity to hold water vapor goes up by 7% for each degree C of warming.[11] While this process has been occurring globally, it has impacted rainfall patterns most severely in Europe, Japan and the US.[12]

For example, in the US the heaviest daily rainfall each year has increased since 1950 in almost 80% of the 244 cities analyzed.[13] There has been a similar trend in Western Europe, where the average spring rainfall has risen since at least the late 20th century (Exhibit 5).

Exhibit 3: **Total Officially Recorded Heat Waves in India by Decade, 2010-2018**



Source: "Extreme Events and Disasters," India Meteorological Department, Ministry of Earth Sciences, 2019.

[ii] Defined as days where precipitation falls within the top one percentile of average precipitation for the specified time period.

Desertification, drought and wildfires

With rising weather variability and changes in rainfall patterns, some parts of the world are becoming markedly more arid. Southern Europe provides a compelling example. It is relatively common to hear warnings of the Sahara Desert creeping northwards and even jumping the Mediterranean Sea.[14] In reality, this process is well underway. Warming temperatures and variations in rainfall patterns have already led to growing desertification in parts of Portugal, Spain, Greece and Italy, with the change visible even over the last 10 years.[iii] As recently as 2019, hot desert air from the Sahara reached France, generating temperatures of nearly 46°C (115°F).[15]

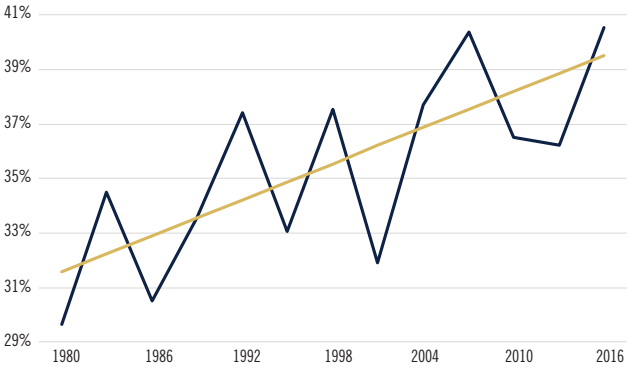
Increasing aridity has in turn led to more frequent and severe wildfires and droughts with a growing proportion of global vegetation exposed to ever-longer wildfire seasons.[16] Indeed, the 2019-2020 wildfires in Australia, Europe and the United States have been some of the most intense and damaging wildfires in recorded history.

As for droughts, the eastern Mediterranean region – Cyprus, Israel, Lebanon and Turkey – has been in a near continuous drought since 1998 with 50% less groundwater than the driest period in the past 500 years.[17] In the past decade, California also had its worst drought in over 1,200 years.[18]

Flooding

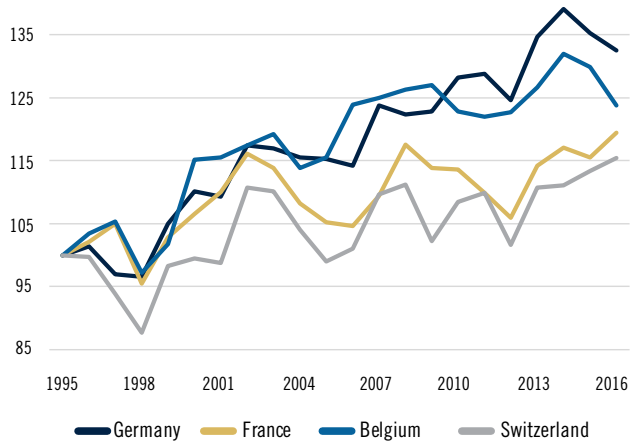
Perhaps the most visible impact of climate change has been the increase in flooding – both coastal and inland. Hotter temperatures and melting polar ice

Exhibit 4: **Storms Are Getting More Intense**
Proportion of Global Major Hurricanes (Category 3-5) to Total Hurricanes, 1979-2017



Source: James P. Kossin, et al., "Global increase in major tropical cyclone exceedance probability over the past four decades," Proceedings of the National Academy of Sciences of the US, May 18, 2020
Note: Points represent three-year averages

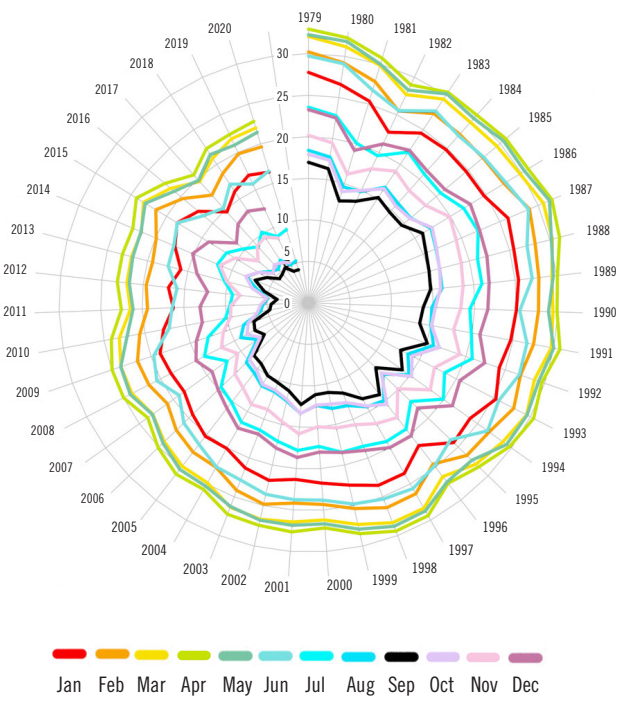
Exhibit 5: **Average Rainfall Has Been Increasing Across Many European Countries**
10-Year Rolling Average Rainfall in May (Indexed to 1995)



Source: PGIM analysis; "Climate Change Knowledge Portal," World Bank, accessed 2020

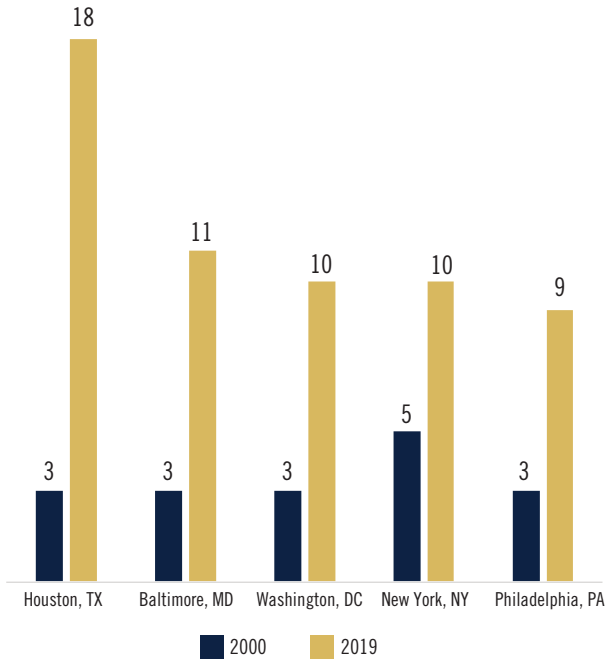
[iii] Desertification is generally defined by six dimensions: water erosion, wind erosion, vegetation degradation/loss, salinization, soil compaction, and soil fertility decline.

Exhibit 6: **Arctic Sea Ice Is Receding**
Sea Ice Volume (1,000 km³)



Source: Ben Horton, "Arctic Death Spiral," accessed 2020

Exhibit 7: **More Frequent "Sunny Day Floods" in Major US Cities**



Source: "The State of High Tide Flooding and Annual Outlook," US National Oceanic and Atmospheric Administration, 2020

caps directly contribute to the rise in average sea level, which accelerated in recent decades (Exhibit 6). According to NASA, the global sea level at the end of 2019 was the highest in recorded history – 3.8 inches above the 1993 average.[19]

As a result, coastal ocean flooding has risen dramatically. This not only means stronger storm surges and rising saltwater contaminating groundwater, but also more frequent flooding at high tide even without severe rain events. These so called "sunny day floods" have become more frequent across many major metropolitan areas in the US since 2000 (Exhibit 7). In Southeast Asia, Jakarta, Manila, Bangkok, Ho Chi Minh City and Hanoi are also experiencing tidal flooding at an increasing rate. This is part of the rationale for Indonesia relocating its capital away from Jakarta.[20]

> *The next two decades of climate change have already been largely determined.*

Flooding is not limited to coastal regions either. More intense and frequent downpours have led to an increased incidence of flooding episodes further inland as well. River floods have become more common in Northwestern and Central Europe, caused by increasing autumn and winter rainfall.[21] An extreme occurrence in 2013 culminated in widespread flooding in Germany, Austria, Slovakia and the Czech Republic.[22] More rapid glacial melts can also contribute to river flooding, especially in the Himalayas.[23] In the US, a significant increase in the number of heavy precipitation days across the Midwest has contributed to massive flood events due to swelling rivers.[24] 2019 was a particularly difficult year for the Midwest and South when the Mississippi River crested.[25]

The planet's transformation will continue under all plausible scenarios

The next two decades of climate change have already been largely determined. Irrespective of the near-term forecast for carbon pricing or renewable energy, there is little variation and uncertainty in the trajectory of climate change for the next 20 years. That is because today's climate change is the result of greenhouse gases (GHG) emitted decades ago. Likewise, today's actions around GHG emissions will only alter climate outcomes decades from now.[26]

For example, the annual probability of a severe drought in China increases by roughly the same amount through 2040 under either rosy or gloomy climate scenarios. Similarly, Brazil will experience a significant increase in the number of dangerous heat days under either scenario.

Perhaps even more telling, these changes under the most optimistic scenario (RCP 2.6) remain significant through 2040, implying that even if the world were to drastically cut its emissions today, the impacts of climate change will still be felt over the investment horizon of most institutional investors (Box 1).

Box 1: **Representative Concentration Pathways**

In the scientific community, the most cited climate scenarios are the Representative Concentration Pathways (RCPs), developed in 2010 and adopted by the United Nations' Intergovernmental Panel on Climate Change (IPCC). Four key scenarios are defined as (1) very low emissions (RCP 2.6), (2) medium-low emissions (RCP 4.5), (3) medium-high emissions (RCP 6.0), and (4) high emissions (RCP 8.5) (Exhibit 8). The RCPs provide a useful framework to understand how climate change may impact the economy, policy and the environment. The various scenarios account for a range of complex interactions between environmental, political, and economic systems. These pathways continue to evolve as our planet transforms and our understanding of climate change progresses.

There are clear differences between climate scenarios, especially between the most optimistic (RCP 2.6) and the most pessimistic scenario (RCP 8.5). However, even these extreme projections have a very similar path of climate change for the next two decades. That is, the bookend 2.6 and 8.5 scenarios only begin to diverge after roughly 20 years. Of course, from a 100-year perspective the planet could follow a range of outcomes, with major societal implications, but in many ways our climate destiny through 2040 is already determined.

Name	Temperature Rise by 2100 (°C)	Description of Scenario
RCP 2.6 (Most Optimistic)	1.5	There is stringent mitigation with a peak and decline of greenhouse gas emissions starting around 2020. CO_2 concentrations peak around 2050, followed by a modest decline by the end of the century.
RCP 4.5	2.4	Overall greenhouse gas emissions remain relatively flat through 2100, except for CO_2 emissions, which begin to decline by around 2050. CO_2 concentrations grow until around 2075 and then begin to level off.
RCP 6.0	3.0	Overall greenhouse gas emissions remain relatively flat through 2100, with CO_2 emissions peaking around 2060 and then declining slightly to level off by 2100. CO_2 concentrations continue to rise through 2100.
RCP 8.5 (Most Pessimistic)	4.9	Greenhouse gas emissions rise exponentially through around 2070 and then grow at a slower rate through 2100. CO_2 concentrations rise exponentially through 2100.

Heightened risk of tipping points and feedback loops

There is increasing evidence the world is reaching tipping points in climate change that will have lasting, irreversible impacts.[27] These tipping points could create a cascading chain of events that accelerate climate change even further. In fact, a major reason for initial calls to limit warming to 2 degrees Celsius was research showing the risk of tipping points goes up exponentially around that level. However, a recent study in *Nature* suggests such tipping points could be triggered with even moderate warming, far lower than previous predictions.[28] With the global average temperature already rising about 1°C, some tipping points may already have been reached. No amount of reduction in greenhouse emissions today could alter that course for the next few decades.

The prevalence of feedback loops in the global climate system make adverse environmental impacts exceedingly difficult to control and limit. For example, about 30% of the energy reaching Earth from the sun is reflected back into space. As a highly reflective surface, ice plays a major role in this. Therefore, as the polar ice caps melt, less of the sun's energy gets reflected back into space and instead is absorbed by land and water – leading to more ice melt. Similarly, as the Arctic permafrost melts, more carbon dioxide and methane that have been trapped in it for centuries get released into the atmosphere, accelerating the very warming that melted the permafrost in the first place.

The critical takeaway for investors is clear: even under the most benign scenarios, our planet and climate will continue to change rapidly. Regardless of whether investors tilt towards ESG objectives, the sweeping impact of climate change across geographies and industries cannot be ignored. This creates both new opportunities and risks for investors' portfolios, which we explore over the next four chapters at the macroeconomic, market, asset class and cross-portfolio levels.

Acknowledgments

PGIM gratefully acknowledges the contributions of Four Twenty Seven and Greenwich Associates to this report, as well as the following individuals:

Natalie Ambrosio Preudhomme, Director, Four Twenty Seven

Deborah Balk, Professor of Public Affairs in the School of Public and International Affairs at Baruch College, Professor at the CUNY Graduate Center, and Associate Director of the CUNY Institute of Demographic Research

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Dr. Robert Herde, Executive Director at Munich Re

Hiro Mizuno, Special Envoy on Innovative Finance and Sustainable Investing at the United Nations

Trevor Houser, Partner at the Rhodium Group

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Jesse Keenan, Associate Professor at the School of Architecture at Tulane University

Zach Knight, CEO and Co-Founder, Blue Forest Conservation

Jay Koh, Managing Director and Co-founder at the Lightsmith Group

Bob Kopp, Director of the Rutgers Institute of Earth, Ocean & Atmospheric Sciences, Professor in the Department of Earth & Planetary Sciences at Rutgers University, Director of the Climate Impact Lab

Douglass Ostermiller, Managing Director at Guy Carpenter

Amine Ouazad, Professor of Economics at HEC Montréal

Alex Rau, Partner at Environmental Commodity Partners LP

Christof Reinert, Head of Risk Management Partners at Munich Re

Carli Roth, Principal at the Rockefeller Foundation

Mary Schapiro, Head of the TCFD Secretariat and Vice Chair for Public Policy and Special Advisor to the Founder and Chairman at Bloomberg, Former Chair of the U.S. Securities and Exchange Commission

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