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Shareholder Rights Group

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Natural Investments, LLC

Newground Social Investment, SPC

NorthStar Asset Management, Inc.

Pax World Funds

Sustainability Group of Loring, Wolcott & Coolidge, LLC

Trillium Asset Management, LLC

Via Electronic Delivery: Rule-Comments@sec.gov

September 11, 2020

Vanessa Countryman
Secretary
Securities and Exchange Commission
100 F Street, NE
Washington, DC 20549

Re: Proposals on Procedural Requirements and Resubmission Thresholds Under Exchange Act Rule 14a-8 (File Number S7-23-19)

Focus: Impact of Rule Change on Systemic Climate Risks as Identified by CFTC

Dear Ms. Countryman:

I write today on behalf of the Shareholder Rights Group to provide further comment on the above-captioned rulemaking proposal. We wish to add the attached report, *Managing Climate Risk in The U.S. Financial System,* a report of the Climate-Related Market Risk Subcommittee, Market Risk Advisory Committee of the U.S. Commodity Futures Trading Commission (the "Report") to the record of the above-captioned rulemaking. The Report states in its Executive Summary that:

> Climate change poses a major risk to the stability of the U.S. financial system and to its ability to sustain the American economy. Climate change is already impacting or is anticipated to impact nearly every facet of the economy, including infrastructure, agriculture, residential and commercial property, as well as human health and labor productivity. Over time, if significant action is not taken to check rising global average temperatures, climate change impacts could impair the productive capacity of the economy and undermine its ability to generate employment, income, and opportunity. Even under optimistic emissions-reduction scenarios, the United States, along with countries around the world, will have to continue to cope with some measure of climate change-related impacts.
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> This reality poses complex risks for the U.S. financial system. Risks include disorderly price adjustments in various asset classes, with possible spillovers into different parts of the financial system, as well as potential disruption of the proper functioning of financial markets…

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> The central message of this report is that U.S. financial regulators must recognize that climate change poses serious emerging risks to the U.S. financial system, and they should move urgently and decisively to measure, understand, and address these risks. Achieving this goal calls for strengthening regulators' capabilities, expertise, and data and tools to better monitor, analyze, and quantify climate risks. It calls for working closely with the private sector to ensure that financial institutions and market participants do the same. And it calls for policy and regulatory choices that are flexible, open-ended, and adaptable to new information about climate change and its risks, based on close and iterative dialogue with the private sector.

The Report calls for sweeping regulatory action by the SEC. The Commission issued an interpretive guidance on disclosure of climate risks and opportunities in 2010[1], which was followed by years of investor requests and petitions[2] for more formal regulatory action, but there has been no evidence of Commission interest in addressing these important issues through a binding regulation.

As we have noted in prior comments, the impending rulemaking appears to have the intended effect of reducing the number of shareholder proposals eligible to appear on corporate proxy statements, including proposals that seek to fill the information gaps identified in the Report on a company by company basis. Until such time as the SEC acts, the shareholder proposal process represents a leading mechanism by which shareholders can work to advance the goals of disclosure and risk management put forth by the Report on a private ordering basis. Such an approach depends on shareholder proposals filed at companies on an individualized basis, but ultimately may lead to generalized practices in the market that could fulfill at least some of the informational needs identified by the Report.

The Commission has an obligation to consider the systemic economic impacts[3] of the rule changes. Any benefits of the rulemaking proposal must be evaluated against the lost economic benefits associated with eliminating shareholder proposals that would otherwise address the

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[1] https://www.sec.gov/rules/interp/2010/33-9106.pdf

[2] https://www.sec.gov/rules/petitions/2018/petn4-730.pdf, https://www.sec.gov/rules/petitions/2020/petn4-763.pdf

[3] As noted in the Report on page 79:

> Climate risk is in part a manifestation of the failure of the current economic system to price externalities and capture them in current accounting, performance measurement, and incentive systems. Scenarios help elucidate the nature of the externalities and translate climate risk into financial risk. Climate risk derives in part from a lack of policies, like a price on carbon, that would internalize the external costs of damaging emissions, but it also comes from traditional accounting practices that ignore these externalities and the prospect of their regulation. This mispricing naturally leads to the misallocation of capital, including the continuing distortions in energy systems that promote climate change.

various subject matters, including climate change. In light of the systemic impacts of climate change, and the potential elimination of 37% or more of shareholder proposals, including those directed toward mitigating such climate disruption risks, we would expect the SEC's economic analysis of the rulemaking to include assessment of the lost benefits to the economy associated with curtailing such proposals. An appropriate economic analysis would need, with regard to systemic climate risk, to address issues such as the following:

- "[M]eaningfully compare the proposed action [the proposed rulemaking] with reasonable alternatives, including the alternative of not adopting a rule."[4]

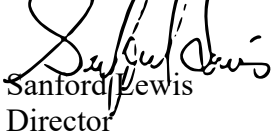
- "[F]rame costs and benefits neutrally and consistently" and combine the economic analysis considering costs and benefits with consideration of the effects on efficiency, competition, and capital formation.[5]

- If the Commission believes that no "reliable basis" exists for estimating costs and benefits of a rule, the courts have stated it must "hazard a guess."[6] Even if estimating lost benefits in reducing systemic risk is difficult, the Commission must put forth a reasoned effort to do so.

In light of the Report from the Commodity Futures Trading Commission, we recommend that the Commission take no action on the proposed rule at its open meeting on September 16. Instead this proposal should be table until the Staff can prepare a new and more thoroughgoing economic analysis in which the impact on such systemic risks is appropriately and accurately assessed, and that new proposal is re-issued with ample opportunity for public notice and comment.

Thank you for consideration of these comments.

Respectfully submitted,



Sanford Lewis
Director
Shareholder Rights Group

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[4] Memorandum to Staff of the Rulewriting Divisions and Offices Re: Current Guidance on Economic Analysis in SEC Rulemakings, March 16, 2012, at 1.
https://www.sec.gov/divisions/riskfin/rsfi_guidance_econ_analy_secrulemaking.pdf.
[5] *Id. at 14.*
[6] *Chamber of Commerce of the United States of America v Securities and Exchange Commission*, 412 F.3d 133 (D.C. Cir. 2005) at 143.

MANAGING CLIMATE RISK IN THE U.S. FINANCIAL SYSTEM

Report of the Climate-Related Market Risk Subcommittee,
Market Risk Advisory Committee of the
U.S. Commodity Futures Trading Commission

Commissioner Rostin Behnam, Sponsor

Bob Litterman, Chairman

To view individual subcommittee members' concurring statements, if any, please see cftc.gov.

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This report is approved by the Subcommittee on Climate-Related Market Risk of the Market Risk Advisory Committee (MRAC). The views, analyses, and conclusions expressed herein reflect the work of the Subcommittee on Climate-Related Market Risk of the MRAC, and do not necessarily reflect the views of the MRAC, the Commodity Futures Trading Commission or its staff, or the U.S. Government. Reference to any products, services, websites, organizations, or enterprises, or the use of any organization, trade, firm, or corporation name is for informational purposes only and does not constitute endorsement, recommendation, or favoring by the U.S. Government.

MANAGING CLIMATE RISK IN THE U.S. FINANCIAL SYSTEM

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David Gillers, Chief of Staff, Office of Commissioner Behnam
Bob Litterman, Chairman
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Executive Summary

Climate change poses a major risk to the stability of the U.S. financial system and to its ability to sustain the American economy. Climate change is already impacting or is anticipated to impact nearly every facet of the economy, including infrastructure, agriculture, residential and commercial property, as well as human health and labor productivity. Over time, if significant action is not taken to check rising global average temperatures, climate change impacts could impair the productive capacity of the economy and undermine its ability to generate employment, income, and opportunity. Even under optimistic emissions-reduction scenarios, the United States, along with countries around the world, will have to continue to cope with some measure of climate change-related impacts.

This reality poses complex risks for the U.S. financial system. Risks include disorderly price adjustments in various asset classes, with possible spillovers into different parts of the financial system, as well as potential disruption of the proper functioning of financial markets. In addition, the process of combating climate change itself—which demands a large-scale transition to a net-zero emissions economy—will pose risks to the financial system if markets and market participants prove unable to adapt to rapid changes in policy, technology, and consumer preferences. Financial system stress, in turn, may further exacerbate disruptions in economic activity, for example, by limiting the availability of credit or reducing access to certain financial products, such as hedging instruments and insurance.

A major concern for regulators is what we don't know. While understanding about particular kinds of climate risk is advancing quickly, understanding about how different types of climate risk could interact remains in an incipient stage. Physical and transition risks may well unfold in parallel, compounding the challenge. Climate risks may also exacerbate financial system vulnerabilities that have little to do with climate change, such as historically high levels of corporate leverage. This is particularly concerning in the short- and medium-term, as the COVID 19 pandemic is likely to leave behind stressed balance sheets, strained government budgets, and depleted household wealth, which, taken together, undermine the resilience of the financial system to future shocks.

The central message of this report is that U.S. financial regulators must recognize that climate change poses serious emerging risks to the U.S. financial system, and they should move urgently and decisively to measure, understand, and address these risks. Achieving this goal calls for strengthening regulators' capabilities, expertise, and data and tools to better monitor, analyze, and quantify climate risks. It calls for working closely with the private sector to ensure that financial institutions and market participants do the same. And it calls for policy and regulatory choices that are flexible, open-ended, and adaptable to new information about climate change and its risks, based on close and iterative dialogue with the private sector.

At the same time, the financial community should not simply be reactive—it should provide solutions. Regulators should recognize that the financial system can itself be a catalyst for investments that accelerate economic resilience and the transition to a net-zero emissions economy. Financial innovations, in the form of new financial products, services, and technologies, can help the U.S. economy better manage climate risk and help channel more capital into technologies essential for the transition.

Findings of the Report

This report begins with a fundamental finding—financial markets will only be able to channel resources efficiently to activities that reduce greenhouse gas emissions if an economy-wide price on carbon is in place at a level that reflects the true social cost of those emissions. Addressing climate change will require policy frameworks that incentivize the fair and effective reduction of greenhouse gas emissions. In the absence of such a price, financial markets will operate suboptimally, and capital will continue to flow in the wrong direction, rather than toward accelerating the transition to a net-zero emissions economy. At the same time, policymakers must be sensitive to the distributional impacts of carbon pricing and other policies and ensure that the burden does not fall on low-to-moderate income households and on historically marginalized communities. This report recognizes that pricing carbon is beyond the remit of financial regulators; it is the job of Congress.

A central finding of this report is that climate change could pose systemic risks to the U.S. financial system. Climate change is expected to affect multiple sectors, geographies, and assets in the United States, sometimes simultaneously and within a relatively short timeframe. As mentioned earlier, transition and physical risks—as well as climate and non-climate-related risks—could interact with each other, amplifying shocks and stresses. This raises the prospect of spillovers that could disrupt multiple parts of the financial system simultaneously. In addition, systemic shocks are more likely in an environment in which financial assets do not fully reflect climate-related physical and transition risks. A sudden revision of market perceptions about climate risk could lead to a disorderly repricing of assets, which could in turn have cascading effects on portfolios and balance sheets and therefore systemic implications for financial stability.

At the same time, this report finds that regulators should also be concerned about the risk of climate-related "sub-systemic" shocks. Sub-systemic shocks are defined in this report as those that affect financial markets or institutions in a particular sector, asset class, or region of the country, but without threatening the stability of the financial system as a whole. This is especially relevant for the United States, given the country's size and its financial system, which includes thousands of financial institutions, many regulated at the state level. Sub-systemic shocks related to climate change can undermine the financial health of community banks, agricultural banks, or local insurance markets, leaving small businesses, farmers, and households without access to critical financial services. This is particularly damaging in areas that are already underserved by the financial system, which includes low-to-moderate income communities and historically marginalized communities.

The report finds that, in general, existing legislation already provides U.S. financial regulators with wide-ranging and flexible authorities that could be used to start addressing financial climate-related risk now. This is true across four areas—oversight of systemic financial risk, risk management of particular markets and financial institutions, disclosure and investor protection, and the safeguarding of financial sector utilities. Presently, however, these authorities and tools are not being fully utilized to effectively monitor and manage climate risk. Further rulemaking, and in some cases legislation, may be necessary to ensure a coordinated national response.

While some early adopters have moved faster than others in recent years, regulators and market participants around the world are generally in the early stages of understanding and experimenting with how best to monitor and manage climate risk. Given the considerable complexities and data challenges involved, this report points to the need for regulators and market participants to adopt pragmatic approaches that stress continual monitoring, experimentation, learning, and global coordination. Regulatory approaches in this area are evolving and should remain open to refinement, especially as understanding of climate risk continues to advance and new data and tools become available.

Insufficient data and analytical tools to measure and manage climate-related financial risks remain a critical constraint. To undertake climate risk analysis that can inform decision-making across the financial system, regulators and financial institutions need reliable, consistent, and comparable data and projections for climate risks, exposure, sensitivity, vulnerability, and adaptation and resilience. Demand will likely grow for public and open access to climate data, including for primary data collected by the government. Public data will enable market participants to, among other things, compare publicly available disclosure information and sustainability-benchmarked financial products. At the same time, proprietary data and analytical products can introduce innovations that improve climate risk management. A key challenge will be how best to balance the need for transparency through public data on one hand, with the need to foster private innovation through proprietary data, on the other.

The lack of common definitions and standards for climate-related data and financial products is hindering the ability of market participants and regulators to monitor and manage climate risk. While progress has been made in this area thanks to voluntary disclosure frameworks and work by foreign regulators, the lack of standards, and differences among standards, remains a barrier to effective climate risk management. The problem is compounded by a lack of international coordination on data and methodology standards. A common set of definitions for climate risk data, including modeling and calculation methodologies, is important for developing the consistent, comparable, and reliable data required for effective risk management. Also, taxonomies or classification systems can help foster greater transparency and comparability in markets for financial products labeled as "green" or "sustainable."

Climate-related scenario analysis can be a useful tool to enable regulators and market participants to understand and manage climate-related risks. Scenarios illustrate the complex connections and dependencies across technologies, policies, geographies, societal behaviors, and economic outcomes as the world shifts toward a net-zero emissions future. Scenario analysis can help organizations integrate climate risks and opportunities into a broader risk management framework, as well as understand the potential short-term impact of specific triggering events. Scenario analysis is gaining traction in several contexts, both domestically and internationally, and regulators are increasingly using scenario analysis to foster greater risk awareness among financial market actors.

Yet, the limitations of scenario analysis should be recognized. While useful, climate scenarios and the models that analyze them have important limitations. Scenarios are sensitive to key assumptions and parameters, most have been developed for purposes other than financial risk analysis, and they cannot fully capture all the potential effects of climate- and policy-driven outcomes. Scenario analysis should have a valuable place in the risk management toolkit, but it should be used with full awareness of what it can and cannot do.

The disclosure by corporations of information on material, climate-related financial risks is an essential building block to ensure that climate risks are measured and managed effectively. Disclosure of such information enables financial regulators and market participants to better understand climate change impacts on financial markets and institutions. Issuers of securities can use disclosure to communicate risk and opportunity information to capital providers, investors, derivatives customers and counterparties, markets, and regulators. Issuers of securities can also use disclosures to learn from peers about climate-related strategy and best practices in risk management. Investors can use climate-related disclosures to assess risks to firms, margins, cash flows, and valuations, allowing markets to price risk more accurately and facilitating the risk-informed allocation of capital.

Demand for disclosure of information on material, climate-relevant financial risks continues to grow, and reporting initiatives have led to important advances. Investors and financial market actors have long called for *decision useful* climate risk disclosures, and in 2019, more than 630 investors managing more than $37 trillion signed the

Global Investor Statement to Governments on Climate Change, which called on governments to improve climate-related financial reporting. Disclosure frameworks have been developed to enhance the quality and comparability of corporate disclosures, most notably, the Task Force on Climate-related Financial Disclosures (TCFD). Also, in 2010, the U.S. Securities and Exchange Commission (SEC) published *Commission Guidance Regarding Disclosure Related to Climate Change*, which provides public companies with interpretive guidance on existing SEC disclosure requirements as they apply to climate change.

However, the existing disclosure regime has not resulted in disclosures of a scope, breadth, and quality to be sufficiently useful to market participants and regulators. While disclosure rates are trending in a positive direction, an update published by the TCFD found that surveyed companies only provided, on average, 3.6 of the 11 total TCFD recommended disclosures. Large companies are increasingly disclosing some climate-related information, but significant variations remain in the information disclosed by each company, making it difficult for investors and others to understand exposure and manage climate risks. In addition, the 2010 SEC *Guidance* has not resulted in high-quality disclosure across U.S. publicly listed firms; it could be updated in light of global advancements in the past 10 years.

In addition to the absence of an economy-wide carbon pricing regime in the United States, other barriers are holding back capital from flowing to sustainable, low-carbon activities. One involves the misperception among mainstream investors that sustainable or ESG (environmental, social, and governance) investments necessarily involve trading off financial returns relative to traditional investment strategies. Another is that the market for products widely considered to be "green" or "sustainable" remains small relative to the needs of institutional investors. In addition, lack of trust in the market over concerns of potential "greenwashing" (misleading claims about the extent to which a financial product or service is truly climate-friendly or environmentally sustainable) may be holding back the market. And policy uncertainty also remains a barrier, including in areas such as regulation affecting the financial products that U.S. companies may offer their employees through their employer-provided retirement plans.

These barriers can be addressed through a variety of initiatives. For example, a wide range of government efforts—through credit guarantees and other means of attracting private capital by reducing the risks of low-carbon investments—catalyze capital flows toward innovation and deployment of net-zero emissions technologies. A new, unified federal umbrella could help coordinate and expand these government programs and leverage institutional capital to maximize impact and align the various federal programs. Climate finance labs, regulatory sandboxes, and other regulatory initiatives can also drive innovation by improving dialogue and learning for both regulators and market innovators, as well as via business accelerators, grants, and competitions providing awards in specific areas of need. In addition, clarifying existing regulations on fiduciary duty, including for example, those concerning retirement and pension plans, to confirm the appropriateness of making investment decisions using climate-related factors—and more broadly, ESG factors that impact risk-return—can help unlock the flow of capital to sustainable activities and investments.

Derivatives markets can be part of the solution. Refinements or modifications could be made to existing instruments to reduce derivatives market participants' risk exposure. For example, commodity derivatives exchanges could address climate and sustainability issues by incorporating sustainability elements into existing contracts and by developing new derivatives contracts to hedge climate-related risks. New products may include weather, ESG, and renewable generation and electricity derivatives. However, development of new derivatives will require that the relevant climate-related data is transparent, reliable, and trusted by market participants. This also applies to a wide range of asset classes that can direct capital to climate-related opportunities and help manage climate risk.

U.S. regulators are not alone in confronting climate change as a financial system risk; international engagement by the United States could be significantly more robust. Financial regulators and other actors have launched important initiatives to tackle the challenge. The United States already participates in the Basel Committee on Banking Supervision's climate task force, the International Organization of Securities Commissions (IOSCO) sustainable finance network, and relevant committees within the Financial Stability Board (FSB) to study climate-related financial risks. However, at the federal level the United States is not yet a member of the Central Banks and Supervisors Network for Greening the Financial System (NGFS), the Coalition of Finance Ministers for Climate Action, or the Sustainable Insurance Forum (SIF). The Group of Seven (G7) and Group of Twenty (G20), in which the United States plays a central role, could also address this challenge and promote international cooperation, but only if the United States is supportive.

Key Recommendations

The full list of the report's recommendations can be found at the end of relevant chapters and compiled in an annex at the end of this report. Below, we highlight some of the most important.

We recommend that:

- The United States should establish a price on carbon. It must be fair, economy-wide, and effective in reducing emissions consistent with the Paris Agreement. This is the single most important step to manage climate risk and drive the appropriate allocation of capital. (Recommendation 1)

- All relevant federal financial regulatory agencies should incorporate climate-related risks into their mandates and develop a strategy for integrating these risks in their work, including into their existing monitoring and oversight functions. (Recommendation 4.1)

- The Financial Stability Oversight Council (FSOC)—of which the Commodity Futures Trading Commission (CFTC) is a voting member—as part of its mandate to monitor and identify emerging threats to financial stability, should incorporate climate-related financial risks into its existing oversight function, including its annual reports and other reporting to Congress. (Recommendation 4.2)

- Research arms of federal financial regulators should undertake research on the financial implications of climate-related risks. This research program should cover the potential for and implications of climate-related "sub-systemic" shocks to financial markets and institutions in particular sectors and regions of the United States, including, for example, agricultural and community banks and financial institutions serving low-to-moderate income or marginalized communities. (Recommendation 4.3)

- U.S. regulators should join, as full members, international groups convened to address climate risks, including the Central Banks and Supervisors Network for Greening the Financial System (NGFS), the Coalition of Finance Ministers for Climate Action, and the Sustainable Insurance Forum (SIF). The United States should also engage actively to ensure that climate risk is on the agenda of G7 and G20 meetings and bodies, including the FSB and related committees and working groups. (Recommendation 4.6)

- Financial supervisors should require bank and nonbank financial firms to address climate-related financial risks through their existing risk management frameworks in a way that is appropriately governed by corporate management. That includes embedding climate risk monitoring and management into the firms' governance frameworks, including by means of clearly defined oversight responsibilities in the board of directors. (Recommendation 4.7)

- Working closely with financial institutions, regulators should undertake—as well as assist financial institutions to undertake on their own—pilot climate risk stress testing as is being undertaken in other jurisdictions and as recommended by the NGFS. This climate risk stress testing pilot program should include institutions such as agricultural, community banks, and non-systemically important regional banks. (Recommendation 4.8) In this context, regulators should prescribe a consistent and common set of broad climate risk scenarios, guidelines, and assumptions and mandate assessment against these scenarios. (Recommendation 6.6)

- Financial authorities should consider integrating climate risk into their balance sheet management and asset purchases, particularly relating to corporate and municipal debt. (Recommendation 4.10)

- The CFTC should undertake a program of research aimed at understanding how climate-related risks are impacting and could impact markets and market participants under CFTC oversight, including central counterparties, futures commission merchants, and speculative traders and funds; the research program should also cover how the CFTC's capabilities and supervisory role may need to adapt to fulfill its mandate in light of climate change and identify relevant gaps in the CFTC's regulatory and supervisory framework. (Recommendation 4.11)

- State insurance regulators should require insurers to assess how their underwriting activity and investment portfolios may be impacted by climate-related risks and, based on that assessment, require them to address and disclose these risks. (Recommendation 4.12)

- Financial regulators, in coordination with the private sector, should support the availability of consistent, comparable, and reliable climate risk data and analysis to advance the effective measurement and management of climate risk. (Recommendation 5.1)

- Financial regulators, in coordination with the private sector, should support the development of U.S.-appropriate standardized and consistent classification systems or taxonomies for physical and transition risks, exposure, sensitivity, vulnerability, adaptation, and resilience, spanning asset classes and sectors, in order to define core terms supporting the comparison of climate risk data and associated financial products and services. To develop this guidance, the United States should study the establishment of a Standards Developing Organization (SDO) composed of public and private sector members. (Recommendation 5.2)

- Material climate risks must be disclosed under existing law, and climate risk disclosure should cover material risks for various time horizons. To address investor concerns around ambiguity on when climate change rises to the threshold of materiality, financial regulators should clarify the definition of materiality for disclosing medium- and long-term climate risks, including through quantitative and qualitative factors, as appropriate. (Recommendation 7.2)

- In light of global advancements in the past 10 years in understanding and disclosing climate risks, regulators should review and update the SEC's 2010 *Guidance* on climate risk disclosure to achieve greater consistency in disclosure to help inform the market. Regulators should also consider rulemaking, where relevant, and ensure implementation of the *Guidance*. (Recommendation 7.5)

- Regulators should require listed companies to disclose Scope 1 and 2 emissions. As reliable transition risk metrics and consistent methodologies for Scope 3 emissions are developed, financial regulators should require their disclosure, to the extent they are material. (Recommendation 7.6)

- The United States should consider integration of climate risk into fiscal policy, particularly for economic stimulus activities covering infrastructure, disaster relief, or other federal rebuilding. Current and ongoing fiscal policy decisions have implications for climate risk across the financial system. (Recommendation 8.1)

- The United States should consolidate and expand government efforts, including loan authorities and co-investment programs, that are focused on addressing market failures by catalyzing private sector climate-related investment. This effort could centralize existing clean energy and climate resilience loan authorities and co-investment programs into a coordinated federal umbrella. (Recommendation 8.2)

- Financial regulators should establish climate finance labs or regulatory sandboxes to enhance the development of innovative climate risk tools as well as financial products and services that directly integrate climate risk into new or existing instruments. (Recommendation 8.3)

- The United States and financial regulators should review relevant laws, regulations and codes and provide any necessary clarity to confirm the appropriateness of making investment decisions using climate-related factors in retirement and pension plans covered by the Employee Retirement Income Security Act (ERISA), as well as non-ERISA managed situations where there is fiduciary duty. This should clarify that climate-related factors—as well as ESG factors that impact risk-return more broadly—may be considered to the same extent as "traditional" financial factors, without creating additional burdens. (Recommendation 8.4)

- The CFTC should coordinate with other regulators to support the development of a robust ecosystem of climate-related risk management products. (Recommendation 8.5)

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List of Acronyms and Abbreviations

AASB	Auditing and Assurance Standards Board
ALM	asset liability management
AMS	American Meteorological Society
Amtrak	National Railroad Passenger Corporation
ASCE	American Society of Civil Engineers
ARPA-E	Advanced Research Projects Agency-Energy
AUASB	Australian Accounting Standards Board
BES	Biennial Exploratory Scenario, Bank of England
BII	BlackRock Investment Institute
BIS	Bank of International Settlements
CA100	Climate Action 100+
CalPERS	California Public Employees' Retirement System
CalSTRS	The California State Teachers' Retirement System
CCAR	Comprehensive Capital Analysis and Review
CCS	carbon capture and storage
CCUS	carbon capture, utilization, and storage
CDI	California Department of Insurance
CDO	Climate Data Online
CDP	formerly, the Climate Disclosure Project
CDS	credit default swap
CDSB	Carbon Disclosure Standards Board
CFTC	Commodity Futures Trading Commission
CMBS	commercial mortgage-backed securities
CME	Chicago Mercantile Exchange
CO_2	carbon dioxide
COSO	Committee of Sponsoring Organizations of the Treadway Commission
COVID-19	Severe Acute Respiratory Syndrome Coronavirus 2
CRD	Corporate Reporting Dialogue
CRE	commercial real estate
CSA	Canadian Securities Administrators
DCM	designated contract markets
DCO	designated clearing organizations
DFA	The 2010 Dodd-Frank Wall Street Reform and Consumer Protection Act
DNB	De Nederlandsche Bank
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DOT	U.S. Department of Transportation

DTCC	Depository Trust and Clearing Corporation
EC	European Commission
ECB	European Central Bank
EIA	U.S. Energy Information Agency
EMMA	Electronic Municipal Market Access
EPA	U.S. Environmental Protection Agency
ERISA	The Employee Retirement Income Security Act of 1974
ERM	enterprise risk management
ESG	environmental, social and governance
ETF	exchange-traded fund
ETS	Emissions Trading System
EU	European Union
EU ETS	European Union Emission Trading System
FAM	Food and Agriculture Microdata Catalogue
Fannie Mae	Federal National Mortgage Association
FAO	Food and Agricultural Organization of the United Nations
FASAB	Federal Accounting Standards Advisory Board
FASB	Financial Accounting Standards Board
FCM	futures commission merchants
FDIC	Federal Deposit Insurance Corporation
FEMA	Federal Emergency Management Agency
FINRA	Financial Industry Regulatory Authority
Fintech	financial technology
FIO	Federal Insurance Office, U.S. Department of the Treasury
FLIGHT	*F*acility *L*evel *I*nformation on *G*reen*H*ouse *G*ases *T*ool
FMU	Financial Market Utilities
Freddie Mac	Federal Home Loan Mortgage Corporation
FSB	Financial Stability Board
FSDA	Future of Sustainable Data Alliance
FSOC	Financial Stability Oversight Council
G7	Group of Seven
G20	Group of Twenty
GAO	U.S. Government Accountability Office
GDP	Gross Domestic Product
GEM	Global Energy Monitor
GFOA	Government Finance Officers Association
GHG	Greenhouse Gases
GHGRP	Greenhouse Gas Reporting Program
GSE	Government Sponsored Enterprises
GRESB	Global Real Estate Sustainability Benchmark
GRI	Global Reporting Initiative
HMC	Harvard Management Company, Inc.
HSFO	high-sulfur fuel oil
IAFP	Investor Agenda Founding Partners
IAIS	International Association of Insurance Supervisors
IEA	International Energy Agency
IFRS	International Financial Reporting Standards
IIRC	International Integrated Reporting Council
ILS	insurance linked securities
IMF	International Monetary Fund
IOSCO	International Organization of Securities Commissions
IPCC	Intergovernmental Panel on Climate Change
IR	Integrated Reporting

IRENA	International Renewable Energy Agency
ISDA	International Swaps and Derivatives Association
ISO	International Organization of Standardization
IWG	Interagency Working Group on the Social Cost of Greenhouse Gases
LMBA	London Bullion Market Association
LMI	low-to-moderate income
LPO	Loan Programs Office
LSFO	low-sulfur fuel oil
MBA	Mortgage Bankers Association
MD&A	Management's Discussion and Analysis
MSP	major swap participants
MSRB	Municipal Securities Rulemaking Board
NAIC	National Association of Insurance Commissioners
NASEM	National Academies of Sciences, Engineering, and Medicine
NCA	4th National Climate Assessment
NCD	non-centrally cleared derivatives
NFIP	National Flood Insurance Program
NFMA	National Federation of Municipal Analysts
NGFS	Central Banks and Supervisors Network for Greening the Financial System
NOAA	National Oceanic and Atmospheric Administration
NYGB	New York Green Bank
OFR	Office of Financial Research, U.S. Department of the Treasury
ORSA	Own Risk Solvency Assessments
OTC	over-the-counter derivatives or swaps
P-ROCC	Physical Risks of Climate Change
PG&E	Pacific Gas & Electric Company
PRA	Prudential Regulatory Authority (United Kingdom)
PRI	Principles for Responsible Investment
RCP	Representative Concentration Pathways
REIT	Real Estate Investment Trust
RFS	Renewable Fuel Standards
RGGI	Regional Greenhouse Gas Initiative
RMBS	residential mortgage-backed securities
RPS	Renewable Portfolio Standard
SASB	Sustainability Accounting Standards Board
SCC	social cost of carbon
SDG	Sustainable Development Goals
SDO	Standards Developing Organization
SEC	U.S. Securities and Exchange Commission
SEF	swap execution facilities
SIF	Sustainable Insurance Forum
TCFD	Task Force on Climate-related Financial Disclosures
TEG	technical expert group
UNEP FI	United Nations Environment Programme Finance Initiative
UNFCCC	United Nations Framework Convention on Climate Change
USCRT	U.S. Climate Resilience Toolkit
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program
VaR	Value at risk
WBCSD	World Business Council for Sustainable Development
WCI	Western Climate Initiative

Foreword

Bob Litterman, Chairman,
Climate-Related Market Risk Subcommittee

As this report is being finalized, the United States is in the midst of a worldwide pandemic, with deaths already exceeding 180,000 from COVID-19, and an associated economic collapse. Of course, there are many differences between the global pandemic, a sudden health crisis that is expected to have impacts of perhaps a few years, and climate change—a global threat that will play out over decades with potentially permanent consequences. But both are similar in one crucial dimension: Science clearly indicates that the cost of delay in responding to the risk can be devastating. A recent study suggests that, in the case of the virus, delaying social distancing by one week in the United States doubled the number of deaths (Pei, et al., 2020). Similarly, every year of delay in the policy response to climate change will lead to a higher mean global temperature increase and to greater probability of irreversible and catastrophic damages. I hope this obvious parallel will help move forward the inevitable global policy response, which in the case of climate change is the creation of incentives to reduce emissions.

The members of the Commodity Futures Trading Commission's Climate-Related Market Risk Subcommittee and I recognize that the financial community must prepare for climate-related risk management challenges. The smooth functioning of the financial markets is crucial to economic prosperity generally, and in particular to facilitating the flow of capital toward mitigating and adapting to climate change. We appreciate Commissioner Rostin Behnam's leadership and timely decision to convene this subcommittee and to request this report to guide the management of climate risk in the U.S. financial system. We also appreciate and thank the Market Risk Advisory Committee (MRAC) and the CFTC for their support. The MRAC's work to examine systemic issues that threaten the stability of the derivatives markets and other financial markets is critical. We hope our recommendations can play an important role in guiding the management of climate risk in the U.S. financial system.

This assignment as chairman of the subcommittee has entailed working with an incredibly talented and dedicated group of climate risk management and financial professionals. In convening the subcommittee, Commissioner Behnam asked many of the most important institutions that participate in the commodity and financial markets to pick a representative who would not only convey their interests, but who could also bring the expertise of the entire organization. These institutions included major banks, an insurance company, energy and agricultural market participants, investors, asset owners, universities, think tanks and non-governmental organizations. This report represents the collective wisdom of this group of professionals and their institutions.

My own background was well suited to lead this effort. I spent a 23-year career in risk management and investing roles at Goldman Sachs. I am well known in the financial community as the co-developer, along with Fischer Black, of the Black-Litterman global asset allocation model, which we created 30 years ago and which is still widely used in the investment industry to build portfolios that optimally balance risk and return. As a result of these experiences, I have a deep respect for the critical role that the financial markets have in facilitating the efficient allocation of capital in our market economy, and the importance of appropriate regulation, oversight, and risk management.

I have a broad background including economics, finance, and risk management, but also a long-term interest in biology, climate change, natural capital, and sustainable finance. As an undergraduate I majored in human biology at Stanford University. My first job was as a general assignment reporter for the San Diego Union. After a year, though, I decided to get a Ph.D. in economics, which I received from the University of Minnesota in 1979. I taught economics at the Massachusetts Institute of Technology for two years, followed by five years at the Federal Reserve Bank of Minneapolis working as a staff economist focused on economic forecasting. In 1986 I moved to Goldman Sachs and began a career on Wall Street as one of the early financial engineers. I started in fixed income research building financial models, followed by a promotion to partner in 1994 when I became the head of firm-wide risk management. In 1998, I moved to the asset management division and headed the quantitative group. In 2009, I left Goldman and helped to create Kepos Capital, a New York based investment management firm where I am currently a partner and chairman of the risk committee.

My focus on climate risk began when I left Goldman Sachs. Like many others, I was concerned that society is not adequately addressing the risks created by climate change. The root cause of climate change is the increase in greenhouse gas (GHG) emissions from humans. As an economist and risk professional, it has long been obvious to me that the risks created by climate change must be addressed by the creation of appropriate incentives to reduce carbon emissions. There is uncertainty about the precise policy levers and tools that will be used to mitigate climate risk, and the innovations that will be required to do so. However, at this moment, what is very clear is that the risks created from climate change are increasing rapidly, economic incentives are misdirected, and immediate action across the global financial system is required.

The Heart of the Matter

A fundamental flaw in the economic system lies at the heart of the climate change problem—the lack of appropriate incentives to reduce GHG emissions. No discussion of climate-related financial risk management can begin without focusing on this market failure. Financial markets do an amazing job of allocating capital in the direction of the incentives that they are given. Appropriate incentives arise in these markets primarily from the prices that balance supply and demand for capital, but that is not always the case.

When negative externalities exist, as is the case with the risks and costs imposed by GHG emissions, there is a role for government to ensure that those externalities are reflected in prices. Unfortunately, that is not happening; emissions remain mispriced and capital is flowing in the wrong direction. In fact, on average, global public policies strongly subsidize carbon emissions from fossil fuel consumption—the International Monetary Fund (IMF) estimated $5.2 trillion (6.5 percent of gross domestic product) in 2017 alone (Coady, et al., 2019). Given the lack of appropriate incentives to reduce emissions, the inevitable responses in economic behavior are directly responsible for the current rapidly accelerating increase in climate risk.

The primary obstacle is political inertia. While there is an ongoing debate about the right price for emissions, what we do know is that inaction creates a large and growing liability. It is very possible that each ton of carbon dioxide put into the atmosphere today will have to be removed and sequestered at some future date to stabilize the world's climate, an expensive process that is not currently feasible and thus a substantial liability that this generation is creating for future generations. If we knew today what it would cost to pull carbon dioxide out of the atmosphere at industrial scale in the not too distant future, the present value of that cost would give us a good sense of an upper bound on where we should price carbon today.

But, because the future is very uncertain, society today should err on the side of caution. In the context of pricing climate risk, that implies imposing a higher price than what models used to calculate the social cost of carbon currently suggest. Prudent risk management calls for immediately implementing carbon pricing globally to quickly reduce GHG emissions and to try to get the planet to net-zero emissions as soon as possible while ensuring that the costs are shared equitably across society and that the distributional impacts are not regressive. Of course, policy should respond to new information over time, and it is very likely that circumstances will require that we need to go beyond net-zero and pull greenhouse gases out of the atmosphere.

Managing Climate Risk

How should financial markets and regulators respond in the face of this enormous market failure? Nearly everyone in the financial markets understands several fundamental principles of risk management. The first is that you must think about worst case scenarios. Of course, only rarely is there a well-defined "worst case." In the financial community, we generally use

the expression "extreme, but plausible" to communicate a common-sense understanding of this type of risk scenario. In this report, we explore a variety of risks, including those that are extreme but plausible, which challenge the stability of the U.S. financial system.

Second, it is well understood that the purpose of risk management is to recognize risks and to warn when they are not being priced appropriately. Markets are in equilibrium when assets reflect not only the expected outcome, but when investors are paid an appropriate premium for the risks that they take. In the case of climate risk, neither the expected impacts—nor the potential for extremely bad outcomes—is being priced appropriately.

Third, time is of the essence. Given enough time, virtually any problem can be addressed. But in risk management, time is a scarce resource. When time runs out, risk can turn into catastrophe. With climate change, we do not know precisely when the planet's climatic system will be pushed past catastrophic tipping points, beyond which financial (and other) consequences would become non-linear. Indeed, some scientists argue that there are thresholds which are very close or may have already been crossed. This uncertainty about thresholds is a powerful reason not to delay.

Finally, in financial markets we often distinguish between risk and uncertainty. Risk generally refers to a model-based statistical measure of a probabilistic distribution, such as volatility or Value-At-Risk (VaR). But we recognize that the real world does not behave according to a model. Our models give us measures of risk, but what we manage in the financial markets is the broader concept of uncertainty, the full potential of bad outcomes when our models are wrong. Similarly, with respect to climate change, the consequences are highly uncertain. After all, this is the first time we have performed this planetary experiment. This uncertainty means that in managing climate risk we must err on the side of caution if we are to maintain the relative stability and proper functioning of our market economies.

Unlike most financial risks, climate risk has unique characteristics, such as the extended time horizon over which damages are expected to occur, which make it more difficult to measure and manage. For the financial risk management of climate change to succeed, we need to be able to understand how physical climate impacts and the transition to a sustainable economy will affect the valuations of financial instruments. To understand this, regulators, investors, and financial institutions require meaningful data related to risk, as well as analytic tools that can interpret that data.

About This Report

Commissioner Behnam asked me to lead a group of expert market participants to initiate the critical process of moving toward a climate-resilient U.S. financial system. The commissioner asked for a consensus document, and a process that facilitated meaningful conversations among relevant parties on complex issues that do not fit neatly into the current regulatory

structure. I think we accomplished that task, and we found plenty to agree on. Our toughest challenge was to keep the report to a manageable length.

What did we agree on? Let's start with the need for appropriate incentives. We all see that appropriate incentives are fundamental to the efficient allocation of capital. They are urgent, they are missing, and need to be addressed. Financial markets today are not pricing climate risk. The financial markets cannot do that on their own. Until this fundamental flaw is fixed, capital will flow in the wrong direction. That is the context for, but not the focus, of this report.

This report reflects agreement around a set of fundamental principles beyond pricing carbon, such as the need for collaboration with international efforts to address climate-related financial market risk. Ultimately, these principles coalesce around the need for leadership by the financial regulators to guide an iterative process forward while leaving room for American financial innovation. It also reflects a consensus about immediate next steps, such as the need to quickly improve the quality of the data, analytics, and understanding of the many dimensions of climate risk. We have also pointed out approaches to scenario analysis, stress testing, and standardization of definitions that will help move us forward on what will no doubt be a complex, iterative path toward the development of meaningful disclosure of material climate risk information—a goal toward which we all agree we must move more quickly.

Although we have not resolved all of the many difficult issues that need to be addressed, we hope that we have succeeded in developing a pragmatic platform for managing the risks and opportunities of climate change. This report makes recommendations to the CFTC but, recognizing that no one regulator can address climate risk in isolation, we also address this report to the wider financial community and Congress.

Investors and financial markets are poised to deliver the low-carbon capital and infrastructure that our global economy requires to address climate risk. We know what we need to do and how to do it. We are impatiently waiting for the appropriate incentives and other policies to reduce emissions to be instituted through legislation. Only then will the awesome power of the financial system be able to address at scale this existential threat.

Why am I so passionate about climate risk? The answer is easy. Like others, I see what is already happening—entire regions burned by increasing wildfires, larger storms, more frequent floods, ecosystems under mounting stress, major health impacts, and climate refugees. In addition, I worry about the future my four grandchildren will likely experience in the coming decades, along with the rest of their generation. Our decisions today will have a major impact on the quality of their lives. Those of us who see the danger, recognize the required path forward, and understand the urgency of taking action must muster the courage and clarity of vision to do what is required now to get us on that path.

Chapter 1

Introduction to Finance in the Face of Climate Change

While this report will be presented to the U.S. Commodity Futures Trading Commission (CFTC), its conclusions and recommendations will also be relevant to other federal and state financial regulators, federal and state lawmakers, leaders in finance and business, and the general public. Its objective is to analyze the existing and emerging risks that climate change poses to the soundness and stability of the U.S. financial system, and offer recommendations. The report considers the risk of climate change impacts, such as sea-level rise, extreme weather events, and rising temperatures, for economic activity and financial markets. It also takes into account the risks posed to the U.S. financial system by shifts in policy, technology, and consumer preferences—shifts that will be necessary to stabilize concentrations of greenhouse gases (GHGs) and reduce the risk of the most damaging impacts of climate change.

Importantly, since climate change will remain a matter of growing legislative interest, the report should help inform policy debates in the U.S. Congress and state legislatures. Finally, the report's recommendations should be of interest to the American people, who would ultimately benefit if our country can better manage one of the most significant threats it faces.

Over the past decade, financial regulators, business leaders, and legislators around the world have recognized the urgency of the challenge and embraced the need to better manage climate-related financial and market risks. Many countries have adopted legislation, guidance, and other initiatives to advance this goal. In addition, myriad international initiatives, working groups, task forces, coalitions, and other efforts have emerged to facilitate collaborative solutions and accelerate learning and information exchange. The United States has been involved in, and has even led, some of these international efforts; but it is noticeably absent in others. As the world's largest economy and second-largest emitter of GHGs, the United States must engage in—and lead—these initiatives. They are in the best interest of the nation, particularly since neither climate change nor financial crises respect national boundaries.

At the same time, managing climate-related financial risks requires close attention to the unique circumstances of the United States. They include the idiosyncrasies of our complex system of financial regulation, as well as existing and proposed legislation. It also must take into account the central role that the private sector plays in our financial system, and the importance of consultation and collaboration between the private and public sectors in the design of new policies.

Finally, it is worth noting two interrelated challenges. One is safeguarding the soundness and stability of the financial system in the face of climate change. The main goal here is to responsibly manage climate risk to protect the system's ability to serve the American public, support economic activity and entrepreneurship, and safeguard the assets of millions of savers, retirees, institutions, and businesses. The second challenge involves helping the financial system facilitate the transition to a low-carbon, climate-resilient economy. Central to this challenge is identifying ways financial markets and institutions can channel significantly more capital toward sustainable investments and net-zero-emission activities, including low-carbon and renewable energy, energy efficiency, other net-zero or low-carbon technologies for transportation, industry and agriculture, and resilience against climate impacts. "Net-zero" refers to activities or investments that seek a net neutral balance between GHG emissions produced and removed from the atmosphere.

This report focuses primarily on financial stability in the face of climate change. However, the report devotes a chapter to sustainable investment, recognizing its role in climate risk management and that, ultimately, a stable and well-functioning financial system is incompatible with unmitigated climate change. A world racked by frequent and devastating shocks from climate change cannot sustain the fundamental conditions supporting our financial system. Promoting the transition to a net-zero emissions economy and safeguarding financial stability are consistent, mutually reinforcing objectives.

The State of Play

As a starting point, this report acknowledges the U.S. government's official position on the scientific consensus on the causes, occurrence, and impacts of climate change. Departments and agencies of the U.S. government, as mandated by the Global Change Research Act of 1990 and operating through U.S. Global Change Research Program (USGCRP), must record and report on the scientific consensus on the causes and impacts of climate change. The most recent, officially promulgated report to Congress is known as the Fourth National Climate Assessment (NCA). As reflected in the NCA, the consensus of the U.S. government is that it is "extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century" (Wuebbles, et al., 2017, p. 1).

Limiting GHG concentrations to a level consistent with a warming of well below 2 degrees Celsius above pre-industrial levels—the core objective of the Paris Agreement on climate change—is therefore essential to achieve a reasonable probability of avoiding irreversible, catastrophic impacts. The best current science suggests that, to reach that goal, global emissions must peak during the current decade and then decline rapidly, reaching net-zero by mid-century. Limiting warming to 1.5 degrees Celsius would yield very significant additional benefits in the form of avoided damage to human populations as well as ecosystems (IPCC, 2018).

But, despite efforts by many countries, progress remains insufficient. Current policies put the world on a path toward a future well in excess of 2 degrees Celsius. Despite a short-term reduction in carbon dioxide (CO_2), largely attributed to a transition away from coal, the United States is not on track to meet either its 2020 or 2025 goals under the Paris Accord (UNFCC, 2015; EIA, 2020; EPA, 2020). While the COVID-19 pandemic and its attendant economic contraction will almost certainly significantly reduce emissions globally in 2020 and possibly beyond, those reductions are expected to be temporary in the absence of structural change. In any case, economic collapse is not a viable strategy for stabilizing the world's climate.

The United States' involvement is crucial in global efforts to combat climate change because of its size and economic weight. It is currently second only to China in emitting GHG. Cumulatively, the United States has put more GHGs into the atmosphere than any other country (including the European Union as a whole). It has contributed roughly one-quarter of all CO_2 emitted since the beginning of the Industrial Revolution (Ritchie and Roser, 2017). At the same time, the United States also remains the world's largest and most dynamic economy, as well as one of the largest producers and consumers of fossil fuels and energy generally. The scope and scale of U.S. industrial activity, long-term assets, and large population significantly expose the United States to climate change impacts (USGCRP, 2018).

While climate change is a global phenomenon, with the United States accounting for roughly one-sixth of annual global GHG emissions, U.S. leadership, historically, has been indispensable to global cooperation on climate change. For example, the United States played a key role in negotiating the United Nations Framework Convention on Climate Change, signed by President George H. W. Bush in 1992 and ratified by the U. S. Senate the same year. The United States also played an important role in negotiating the 1997 Kyoto Protocol, while its subsequent failure to ratify the agreement undermined its effectiveness. Ultimately, the United States was a driving force in the design and international adoption of the 2015 Paris Agreement, which has been ratified by 189 countries. That agreement is designed to achieve broad global participation, with all countries accepting responsibility to reduce emissions while balancing national autonomy with a clear expectation of continually increasing ambition. It also promotes transparency about countries' commitments and how well they are meeting those commitments.

While the United States has formally indicated its intention to withdraw from the Paris Agreement in November 2020, other countries are moving ahead. Most notably, the European Union has pledged to reduce emissions by 40 percent below 1990 levels by 2030 and is now moving forward with policies to increase that reduction target to 55 percent. Yet, no country or bloc can meet the global challenge by itself. Renewed U.S. engagement in international climate efforts, and its embrace of policies aimed at decarbonizing the economy, will be necessary to achieve significant, coordinated reductions in global emissions.

The Centrality of Carbon Pricing

The British economist, Lord Nicholas Stern, in his influential *Review of the Economics of Climate Change*, famously called climate change "the greatest and widest-ranging market failure the world has ever seen" (Stern, 2007). From an economic perspective, greenhouse gas pollution is a powerful example of a negative externality. Emissions of CO_2 and other GHGs impose significant damages on society at large in the form of future climate impacts, but at least in the absence of government policy, these damages remain "external" to the calculus of individual economic agents (Stern). In effect, the environmental costs of burning fossil fuels, cutting down tropical forests, and other emitting activities have been treated as if they were "free."

Without an effective price on carbon, financial markets lack the most efficient incentive mechanism to price climate risks. Therefore, all manner of financial instruments—stocks, bonds, futures, bank loans—do not incorporate those risks in their price. Risk that is not quantified is difficult to manage effectively. Instead, it can build up and eventually cause a disorderly adjustment of prices.

The global damage from an additional metric ton of CO_2 is uncertain but is captured in the concept of the "social cost of carbon" (SCC). The U.S. government's central estimate for the 2020 SCC, calculated in 2016, amounts to $52 per metric ton of CO_2 in current dollars (IWG, 2016). However, some scholars have argued that a more comprehensive consideration of damages or risk aversion would likely lead to a significantly higher SCC (Revesz et al., 2014; Daniel et al., 2019). Recent empirical evidence also finds that some measures of climate damages are much higher than previously understood (Hsiang et al., 2017).

The economist's standard policy prescription in such cases is to correct the "missing price," by either imposing a tax equal to the marginal social cost of pollution or by establishing an emissions trading system (ETS) that creates a market for emissions reductions (subject to a cap on total pollution across covered facilities) and thus a market price for pollution. Putting a price on GHG emissions, creates an economic incentive to allocate capital toward the development of new, lower-emitting technologies, promoting dynamic efficiency. In many ways, the two types of carbon pricing policies are broadly equivalent in practice.

Some jurisdictions have adopted carbon taxes or emissions trading systems. Eleven U.S. states and two Canadian provinces currently have an ETS. States in the Northeast established the Regional Greenhouse Gas Initiative (RGGI) in 2008. With the addition of Virginia in 2021, it will cover emissions from power generation in 11 states, capturing about 18 percent of total emissions in the region. Launched in 2013, the California Cap-and-Trade Program represents the broadest carbon pricing system in the world, covering 80 percent of the state's GHG emissions. The California program is directly linked to the Quebec system under the umbrella of the Western Climate Initiative (WCI), the first international mechanism linking different sub-national entities. As with RGGI, there are derivatives markets for California carbon allowances, including futures contracts.

The European Union Emission Trading System (EU ETS) remains the largest ETS worldwide, accounting for almost 90 percent of global emission trading volume. The EU ETS is supported by a large secondary market, in which allowances are traded bilaterally or on an exchange-cleared basis. In its next phase (2021 to 2030), the EU ETS will align its goals to the goals of the 2015 Paris agreement. Meanwhile, China is expected to launch a national ETS in 2020 that will initially cover the power sector before expanding to cover seven other industrial sectors by 2025. It has the potential to become the world's largest. Finally, carbon taxes are in place in jurisdictions, including Canada, Chile, Colombia, Mexico, South Africa, Sweden, and the United Kingdom.

Yet, despite these efforts, carbon remains underpriced worldwide. Today, various carbon pricing policies operate in 78 countries, states, provinces, and cities. Together, these initiatives cover about 22 percent of global GHG emissions. However, prices in many jurisdictions remain low, with half of the emissions covered by carbon pricing initiatives priced at $10 per metric ton or less (World Bank, 2020). In 2017, the High-Level Commission on Carbon Prices concluded that a carbon price in 2020 in the range of $40 to $80/t$CO_2$ and rising to $50 to $100/t$CO_2$ by 2030 would be consistent with meeting the temperature target in the Paris Agreement (High-Level Commission on Carbon Prices, 2017). In the absence of effective, broadly applied carbon pricing, financial markets will continue to struggle to motivate economic agents to act in ways compatible with long-term temperature targets.

Various coalitions of governments, non-governmental organizations, and companies in different sectors have issued myriad statements in recent years affirming the importance of carbon pricing. Notable examples include: (i) the Carbon Pricing Statement signed by 73 countries and more than 1,000 companies and investors in 2014; (ii) the 2019 Global Investor Statement to Governments on Climate Change signed by 613 investors with more than $37 trillion in assets; (iii) the Guiding Principles announced by the CEO Climate Dialogue made up of 21 companies and four non-governmental organizations (NGOs) in 2019; (iv) the *Economists' Statement on Carbon Dividends* signed in 2019 by more than 3,500 economists including all four former chairs of the Federal Reserve, 27 Nobel laureates, and 15 former chairs of the Council of Economic Advisers; and, (v) the Vatican Dialogues Participant Statement on Carbon Pricing signed by the CEOs of 10 major oil companies along with major asset managers and others in 2019.

These and other similar statements commonly cite principles for carbon pricing policy that include, (i) *fairness*, with respect to both the incidence of a carbon pricing policy (in other words, how the impacts are distributed among different income groups, as well as how revenue is allocated); (ii) *scope*, in particular whether the carbon pricing policy covers specific sectors or the entire economy; and, (iii) *effectiveness* in achieving emissions reductions and thus limiting warming—a function of the initial price level and how fast it rises, as well as whether the policy establishes an enforceable and stringent limit on emissions.

This report recognizes that all climate policy frameworks should be sensitive to the inequitable burdens of climate change, particularly current and future market failures impacting low- and moderate-income households and historically marginalized communities. To this end, this report highlights the extent to which business-as-usual represents significant risks for not only American financial institutions, but also for American households. However, where there are risks, there are also opportunities for broader advancement in achieving equitable and sustainable prosperity.

U.S. and Global Action on Climate in the Financial Sector

Despite the absence so far of effective carbon pricing globally and in many key jurisdictions, financial regulators and market participants increasingly recognize the need to measure and manage climate risks. Central banks have been especially prominent in calling for efforts to advance that goal. The Central Banks and Supervisors Network for Greening the Financial System (NGFS), chartered in 2017, is a group of central banks and supervisors, "willing, on a voluntary basis, to share best practices and contribute to the development of environment and climate risk management in the financial sector and to mobilize mainstream finance to support the transition to a sustainable economy" (NGFS, 2019). As of June 2020, the group had 66 members and 13 observers, including members from most of the largest global economies and from the New York State Department of Financial Services—but no U.S. federal government entity (NGFS, 2020).

The views of central bankers are illustrative of growing concern about climate risk among financial regulators. U.S. Federal Reserve Board Governor Lael Brainard gave remarks titled *Why Climate Change Matters for Monetary Policy and Financial Stability*, stating, "Congress has assigned the Federal Reserve specific responsibilities in monetary policy, financial stability, financial regulation and supervision, community and consumer affairs, and payments. Climate risks may touch each of these" (Brainard, 2019). In 2018, Benoit Cœuré, then a member of the Executive Board of the European Central Bank (ECB), noted that climate change may warrant monetary policy action, if climate change impacts are so persistent that central banks can no longer "look through" climate change as a short-term shock (Cœuré, 2018). Guy Debelle, deputy governor of the Reserve Bank of Australia, echoed that statement in 2019, saying that central banks should view climate change as a "trend change" with an ongoing rather than temporary impact (Debelle, 2019).

Central banks are increasingly researching climate risk, including parts of the Federal Reserve System. The Federal Reserve Bank of San Francisco organized a conference in November 2019 on "The Economics of Climate Change." The Bank of England, the Bank of Canada and the ECB are all researching how climate change could affect macroeconomic forecasting, systemic risks, and monetary policymaking (Wilkins, 2019; Carney, 2019; Lagarde, 2020). The Basel Committee on Banking Supervision published a survey of its global membership of financial regulators in April 2020. Twenty-four of 27 responding members and observers have conducted research on climate-related financial risks (BIS, 2020).

Central banks and other financial regulators from major economies are focusing on greater disclosure of climate-related risks and opportunities by corporations. In 2015, the Group of Twenty (G20) asked the Financial Stability Board (FSB), composed of financial regulators from the world's largest economies, to consider climate risk. In response, the FSB established the industry-led Task Force on Climate-related Financial Disclosures (TCFD). The FSB initially focused on disclosure because, as noted in the its 2015 response to G20 leaders, "[a]ppropriate disclosure is a prerequisite for both the private sector and authorities to understand and measure the potential effects on the financial sector of climate change, as markets evolve and as the wider economy transitions towards a low-carbon economy" (FSB, 2015, p. 2). The TCFD called for voluntary climate-related financial disclosures that are "consistent, comparable, reliable, clear, and efficient, and provide decision-useful information to lenders, insurers, and investors" (TCFD, 2020a). It also issued recommendations for implementing disclosures. As of February 2020, more than 1,000 companies and other organizations, including private sector organizations with a collective market capitalization of $12 trillion and financial firms responsible for $138.8 trillion of assets, have declared support for the recommendations (TCFD, 2020b).

Insurance regulators are also thinking about the management of climate risk. The Sustainable Insurance Forum (SIF), a network of 31 insurance supervisors and regulators from around the world, was created in 2016 to work on sustainability challenges. Membership includes the U.S. National Association of Insurance Commissioners, the California Department of Insurance, the New York Department of Financial Services, and the Washington State Office of the Insurance Commissioner (SIF, 2020). Its goals are to strengthen insurance supervisors' and regulators' understanding of, and responses to, both sustainability and climate-related challenges and opportunities for the insurance business. The SIF has focused on developing and sharing supervisory best practices to address risks posed by climate change to the insurance sector as a whole and to individual insurance firms as underwriters and investors (SIF/IAIS, 2018; SIF/IAIS, 2020).

Investors—through a variety of formal and informal bodies—also are increasingly focused on climate-related risks. For example, Climate Action 100+ is a group of 450 investors with more than $40 trillion in assets. The group has encouraged "systemically important emitters" to reduce their GHG emissions, as well as to increase board oversight and disclosure (CA100, 2019). The Net-Zero Asset Owner Alliance, established in 2019, is

a group of major institutional investors, managing nearly $4.7 trillion in assets, who have committed to shifting their investment portfolios to net-zero GHG emissions by 2050. Another example is the United Nations Principles for Responsible Investment (PRI) initiative, which requires strategy- and governance-focused climate risk reporting for all of its more than 3,000 signatories, which manage more than $100 trillion in assets (PRI, 2020).

The leaders of some large asset owners and managers have made significant statements about the need to take climate risk seriously. The $1 trillion Norwegian government pension fund, the world's largest sovereign wealth fund, has adopted a detailed set of climate-related expectations for all portfolio companies, covering strategy, risk management, disclosure, and policy (Norges Bank, 2019). The fund has also divested its holdings in certain coal-mining and coal-burning power companies. The California State Teachers' Retirement System (CalSTRS), one of the largest U.S. public pension funds, divested from U.S. thermal coal companies in 2016 and from non-U.S. thermal coal companies in 2017 (CalSTRS, 2016). Larry Fink, CEO of U.S. asset manager BlackRock, which managed nearly $7 trillion in assets in late 2019, has publicly equated climate risk with investment risk and pledged that his company will be increasingly likely to vote against company managers and board directors when companies are not making sufficient progress in sustainable business practices (Fink, 2020).

While U.S. financial institutions have taken some significant steps, most financial sector leadership on climate action has, in recent years, come from outside the United States. European and British regulators, banks, asset owners, and insurers have been especially active. Authorities from China, Mexico, and Canada have also been very engaged. International organizations, including financial standard-setting bodies and the International Monetary Fund have devoted significant time and attention to climate risk management.

Yet, because of its financial system's size and scope, engagement by the United States is crucial if global financial markets are to effectively manage climate risk and facilitate the transition to more resilient, low-to-no-carbon economy. U.S. capital markets, both equities and fixed income, are the largest in the world and among the deepest and most liquid. The largest futures exchange in the world is based in the United States and offers the widest range of products across all asset classes. Four of the five largest asset managers in the world are based in the United States, and the United States represents the largest insurance market globally by premium volume. Without active leadership by U.S. regulators and financial institutions, the mission of prudent climate risk management will remain incomplete at best, and those gaps will remain a key weakness in the U.S. and global financial systems.

Road Map of the Report

The rest of this report focuses on the climate-related risks the U.S. financial system faces and on how regulators and financial institutions can address them. It is divided into eight chapters. This chapter has provided the policy and global context for this report. Chapters 2 and 3 explain the climate-related physical and transition risks that the U.S. economy and financial system face. Chapter 4 examines the challenge of climate risk management from the perspective of financial regulators. It reviews their existing authorities and recommends actions to address the risks outlined earlier in the report.

The remaining four chapters delve into topics of special interest to policymakers and the private sector. Chapter 5 focuses on how financial institutions and firms can manage climate risk, including by using consistent, comparable and reliable climate data and analytics. Chapter 6 looks more closely at climate scenarios and explains how they can provide useful insights that help regulators and companies plan. Chapter 7 looks at the disclosure of climate risk, outlining the evolution of the current disclosure regime and how it can be strengthened. Finally, Chapter 8 explores how the financial system can better facilitate capital flows toward activities and technologies that promote the transition to a resilient, net-zero emissions economy, including new and existing instruments that integrate and help effectively manage climate risk.

Collectively, these chapters provide recommendations that highlight a range of innovations in the public and private sectors that help advance the economic resilience of the U.S. financial system. More fundamentally, these innovations offer the opportunity to adapt the American economy to provide new financial products, services, and technologies to advance a broader global transition that removes or eliminates GHG emissions from the global economy. These innovations and opportunities provide a foundation for Americans to invest in a transition to a more environmentally sustainable and socially equitable future.

Recommendation

Recommendation 1: The United States should establish a price on carbon. It must be fair, economy-wide, and effective in reducing emissions consistent with the Paris Agreement. This is the single most important step to manage climate risk and drive the appropriate allocation of capital.

Chapter 2

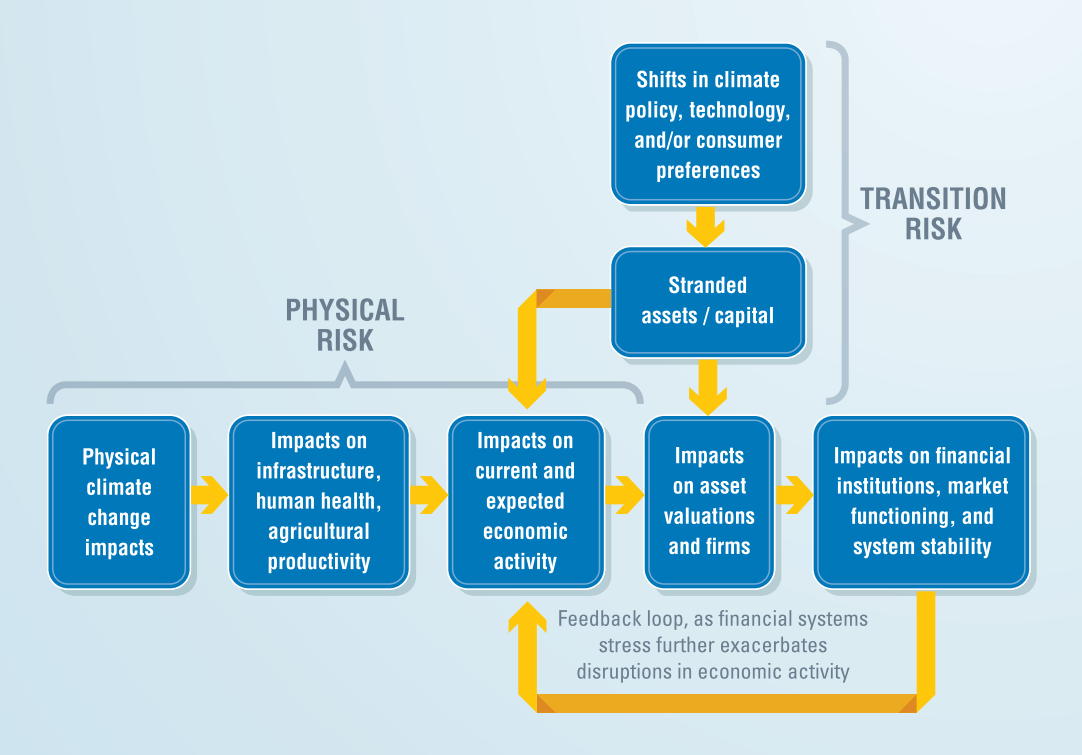
Physical and Transition Risks in the Context of the United States

Climate-related physical and transition risks are already impacting, or are anticipated to impact, nearly every facet of the U.S. economy—a broad cross-section of markets, products, instruments, and services. How material these climate-related risks will be varies depending on time horizon, geographic region, and segment of the economy, as well as on climate mitigation and adaptation actions. If these risks are misunderstood and mismanaged, they could affect financial assets and financial markets, and in turn the ability of the financial system to serve the American economy. As summarized in this chapter, some climate change impacts already can be seen in various asset classes. These impacts ultimately undermine the economic welfare of American households and often disproportionately burden low-to-moderate income (LMI) and historically marginalized communities—further undermining environmental justice.

The risks associated with climate change are many and complex, but for simplicity, they are often divided into physical and transition risk. Physical risk is defined as risk that arises from the material, operational, or programmatic impairment of economic activity and the corresponding impact on asset performance from the shocks and stresses attributable to climate change. Transition risk, on the other hand, is defined as risk associated with the uncertain financial impacts that could result from a transition to a net-zero emissions economy. These risks could arise, for example, from changes in policy, technological breakthroughs, and shifts in consumer preferences and social norms (Bolton, et al., 2020).

Figure 2.1 summarizes the causal chains through which physical and transition risk could affect economic activity and the financial system. While both physical and transition risks can directly impact asset values, the distribution of indirect wealth effects may further impair assets. This chapter focuses on the causal chains ending with impacts on asset values. Chapter 3 focuses on the impacts on financial institutions and possible feedback loops.

Figure 2.1: Relationship Between Physical and Transition Risks



Physical Risks

The measurement and understanding of physical risk vary considerably from sector to sector and remains, overall, in an early stage of development. The impacts of physical risks may also vary significantly within a sector depending on the risk and firms' climate management practices and capacities. In general, physical risks may be either acute or chronic. Their severity depends on the physical exposure of assets, infrastructure, and populations. Advances in attribution science that help distinguish climate trends from natural variability (NASEM, 2016), together with advances in measurement technology, are improving the understanding of physical climate risk (Keenan, 2019). With further advances in technology and standardized disclosure practices, additional physical risks may be discovered, and existing risks will be measured and reported with increasing precision and sophistication. Through stress testing, scenario planning and other analytical measures, sectors and firms may be better prepared to mitigate and adapt to climate change.

Estimates of physical risks are based on a variety of assumptions, scenarios, and Representative Concentration Pathways (RCPs). RCPs are widely used, consensus-based models that estimate how climate systems may respond to specific concentrations of greenhouse gas in the atmosphere. Currently, no standardization exists within or across sectors on which parameters to use for evaluating physical risk, and so these estimates

remain first-order approximations. For instance, there is an ongoing debate concerning the assumptions in RCP 8.5 (the most severe of the RCPs) and whether it underestimates business as usual (Christensen, Gillingham, and Nordhaus, 2018) or overestimates physical and economic impacts by disregarding gradual shifts in the global energy economy (Ritchie and Dowlatabadi, 2017). However, these pathways and associated estimates nevertheless importantly help shape awareness among policymakers and the private sector on the magnitude and nature of the risk.

With those caveats, the latest research suggests that, by the end of this century, the negative impacts on the United States from climate change will amount to about 1.2 percent of annual gross domestic product (GDP) for every 1 degree Celsius increase (Hsiang, et al., 2017). This is roughly the equivalent of wiping out nearly half of average annual GDP growth rates in recent years. There is great uncertainty about how those losses may be distributed across the United States and within any given sector or asset class. But the research suggests that the South, Central and mid-Atlantic regions likely will be more heavily impacted than northern regions. This could affect how capital is distributed among regions (Hsiang, et al.; NGFS, 2019a). The relationship between climate change, warming temperatures, and economic output is not anticipated to be as linear as described in this chapter. Beyond certain ecological and economic thresholds, economic losses could be significantly greater.

Agriculture and Ecosystem Services

Agriculture is an important part of the U.S. economy. In 2017, agriculture, food, and related industries contributed more than $1 trillion, or 5.4 percent of GDP (USDA, 2020). Agricultural producers alone provided more than 3 million jobs in 2019 (USDA). Physical risks to agriculture include a wide range of shocks and stresses. They include, for example, localized heat stress impacting livestock (Rojas-Downing, et al., 2017) and farm workers (Lundgren, et al., 2013; Gubernot, et al., 2014), as well as potential annual productivity declines of 2 to 4 percent under moderate to severe emissions scenarios across the U.S. agricultural economy (Liang, et al., 2017). One study projects that each degree-Celsius increase in global mean temperature could, on average, reduce global yields of wheat by 6 percent; rice by 3.2 percent; maize by 7.4 percent; and, soybeans by 3.1 percent (Zhao, et al., 2017). These potential declines in crop yields undermine the domestic capacity to feed a global population that increases roughly 1.1 percent a year (World Bank, 2019). While the magnitudes of the estimates and the extent to which adaptation may mitigate future losses vary (Burke and Emerick, 2016), there is general agreement that climate change will reduce average yields and total production for most crops in most regions. (Porter et al., 2014). To this end, adaptation measures (for example, micro-irrigation) and resilience technologies (for example, drought-tolerant biotechnology) offer great promise for mitigating potential future declines in agricultural output.

Other risks include degradation in water and soil quality (Gowda, et al., 2018), quantity (Dai and Zhao, 2017), and increased uncertainty and variability in crop and fisheries yields (Walthall, et al., 2012), increased range and virulence of pests (Taylor, et al., 2018), and

more frequent disruptions of distribution and processing from extreme weather (Bakker, et al., 2018). More broadly, climate change is impacting, and is projected to impact, not only commercial agriculture in the United States, but also the ecological systems and biodiversity that agricultural systems rely on for everything from the provision of clean water to healthy forests (Lipton, et al., 2018). Logistical constraints that prevent or delay the shipment of crops, seeds and material, such as when the Mississippi River has too little or too much water to safely support barge traffic, also impact the agricultural economy (Attavanich, et al., 2013).

Financial market participants dealing in agricultural commodities must adapt to this wide range of physical risks by devising new ways to value, price, and manage climate risk. Another key challenge is the future capacity of the U.S. government to provide actuarially sound crop insurance, based on best available data, to support changes in underwriting and pricing attributable to climate change and natural variability (Antóni, et al., 2012; Rosa, 2018). Crop insurance for extreme events that can financially devastate American farmers is a crucial protection. In addition, future public and private investments in adaptation and resilience—water conservation, drought-tolerant crops, and logistics and storage infrastructure—are needed to manage physical risk in the sector.

Infrastructure

Awareness is growing across infrastructure sectors, including energy, water, transportation, and communications, that physical risks do not just impact particular sites and locations (Bertolotti, et al., 2019), but also shorten the lifecycle of infrastructure and degrade its operational reliability (Maxwell, et al., 2018). Even slight degradations in lifecycle performance can compromise the long-term yields and creditworthiness of revenue-producing assets in both the public and private sectors. In addition, there is growing appreciation that disruptions in energy, transportation, and communications infrastructure can impose economic losses on communities, adding to the losses from damage to the infrastructure itself. Even in low-to-middle income countries with significantly less infrastructure than the United States, infrastructure disruptions already impose between $391 billion and $647 billion in annual costs to firms and households (Hallegatte, et al., 2019). It is reasonable to assume that under a business-as-usual scenario annual losses in the United States could far exceed these estimates.

In the context of longstanding deferred maintenance challenges, the U.S. power infrastructure faces significant vulnerabilities from more frequent extreme weather attributed to climate change (ASCE, 2017). Aging infrastructure and climate change will require significant capital investments to ensure compliance with existing reliability and engineering resilience standards for the delivery of electrical power and fuel (DOE, 2017). In addition, regulated utilities are facing increased legal liability from their inability to fully account for and mitigate physical risks (Gundlach, 2020). For example, the 2019 bankruptcy of the Pacific Gas and Electric Company (PG&E) marked the first-ever bankruptcy attributed, in

part, to liabilities arising from climate change-related impacts, namely, record wildfires. PG&E, with $71 billion in assets and $51 billion in debt, was confronted with $30 billion in estimated wildfire liabilities (MacWilliams, et al., 2019).

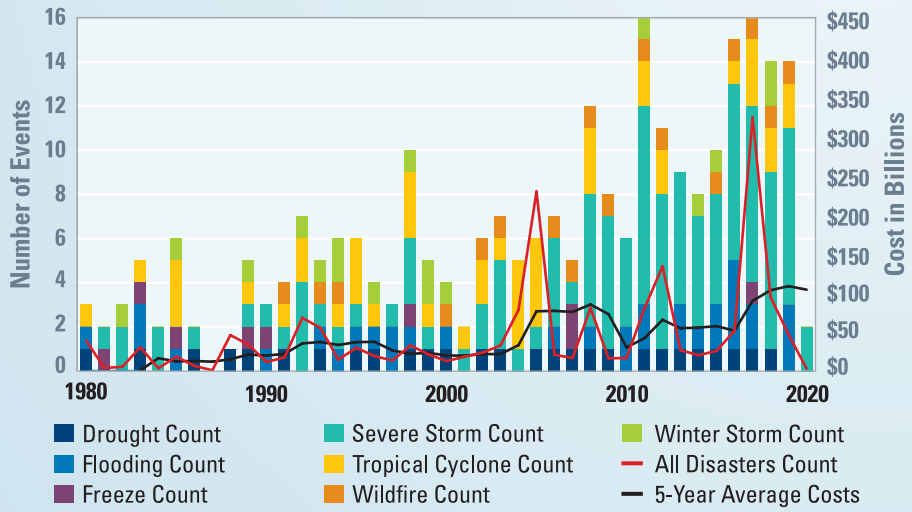
In addition, the adaptation measures themselves—such as periodically cutting-off power in high-risk fire zones in California—may impose collateral economic costs (Ovaere, et al., 2019). Early-stage research suggests electrical transmission and distribution infrastructure costs from climate change could increase 25 percent by 2090 (Fant, et al., 2020). Similar costs associated with climate adaptation and direct losses likely will strain existing utility credit quality and bonding capacity, as well as increase customer costs—potentially limiting broader economic activity.

Transportation and water infrastructure share similar challenges from physical risk. For example, single-point and cascading failures in infrastructure systems can result from accelerated material degradation of concrete, steel, timber and earthen structures from extreme precipitation, extreme temperatures, and changes in relative humidity, salinization, and carbonization (Stewart and Deng, 2015; Bastidas-Arteaga, 2018). Location-specific exposure to extreme precipitation events, coastal flooding, inundation from rising sea levels, extreme heat, icing, subsidence and forest fires challenge nearly every element of transportation systems, from bridges and airports to pipelines and ports (Jacobs, et al., 2018).

The same can be said of infrastructure supporting the treatment, distribution and supply of water (Maxwell, et al., 2018). Even without climate change, significant resources will be required to safeguard water infrastructure. A survey of local governments by the U.S. Environmental Protection Agency estimated that state and local investments of $472 billion (2018) will be required over the next two decades just to maintain drinking water infrastructure (EPA, 2018). One estimate puts future investments to maintain all domestic water infrastructure at $123 billion per year (Ajami, et al., 2018). Climate change impacts likely will add to ongoing capital investment deficits in water infrastructure. Failure to adequately invest in water infrastructure could result in the loss by 2040 of nearly a million jobs that directly depend on water (EPA, 2018).

Growing demand for investments to protect infrastructure from climate-related physical risk are likely to increase fiscal pressure on state and local governments. Many of them are already straining under the weight of unfunded pension obligations and rising healthcare costs (Gilmore and St. Clair, 2018). The COVID-19 pandemic will add to pre-existing fiscal burdens. Some financial markets are beginning to price in the expected fiscal burdens of coping with physical risk. For example, municipal bond markets may already be pricing in exposure to sea level rise in some coastal jurisdictions (Goldsmith-Pinkham, et al., 2019). With greater discovery and reporting of physical risk, many public borrowers may face higher capital costs to compensate investors for higher perceived default risk. That, in turn, will increasingly limit governments' capacity to invest in critical infrastructure and in infrastructure that supports and protects their tax base. It may also result in higher local property and sales taxes.

Figure 2.2: U.S. Billion-Dollar Disaster Events 1980–2020 (CPI-Adjusted)



Updated April 8, 2020

Source: NOAA, National Centers for Environmental Information (2020)

As represented in Figure 2.2, the economic costs of disasters to the public and private sectors have been rising, as represented by the rising incidence of billion-dollar disasters. This is a function of greater exposure of cities, populations and assets, and the greater intensity and frequency of a variety of extreme weather events. Many of these extreme events are already attributable in varying degrees to climate change. For local governments, losses from such extreme events can have fiscal ramifications for many years. Even without climate change, the United States needs to make significant investments in building new infrastructure and maintaining existing infrastructure. Climate change and extreme weather events add additional barriers of cost, time, uncertainty, and risk to these investments.

Commercial and Residential Real Estate

The real estate sector shares similar physical risks with the infrastructure sector. The real estate sector is not only dependent on infrastructure, it also generates local property tax revenue that supports most domestic infrastructure investment in the first place (Shi and Varuzzo, 2020). Since the value of real estate is closely linked to the value of the land it is built on, physical risks, such as wildfires and rising sea levels, can directly affect real estate prices.

Indeed, emerging research shows that exposure to climate-related risks already affects real estate values. For example, research has shown that increased perceptions of physical risk in a local housing market depress the prices of homes exposed to sea level rise

(Giglio, et al., 2015a; Giglio, et al., 2015b). Bernstein, et al. (2019) and Baldauf, et al. (2020) provide evidence that perceptions of flooding-related climate risk are currently priced into some real estate markets. Even in high-value markets, such as Miami, evidence suggests that the price appreciation of properties that have a high risk of climate-attributed flooding may slow relative to lower-risk properties (Keenan, et al., 2018). Similarly, early-stage research has demonstrated that the price of homes drops when they are designated to be in a wildfire risk zone (McCoy and Walsh, 2018; Garnache and Guilfoos, 2019). While climate risk already appears to affect real estate values, these effects likely will increase as physical risks become more frequent and severe. Commercial real estate is particularly vulnerable to the shocks and stresses of climate change that may lead to declines in local GDP, which drives demand for office, industrial, and retail space (BII, 2019).

A decline in real estate values can have larger implications for the U.S. economy and financial sector. For most U.S. households, housing constitutes the largest share of household wealth, and substantial evidence suggests that household spending varies with housing wealth (Mian, et al., 2013; Stroebel and Vavra, 2019). Declining real estate values—driven by climate-related impacts or the perception of such impacts in the future—could substantially depress economic activity. Some populations and local communities within the United States may ultimately be required to relocate, with potentially significant economic losses for households and investors.

Since most residential real estate in the United States is purchased with a mortgage, physical risk could also affect the underlying mortgages. Early-stage research suggests that wildfires and flooding cause increased residential mortgage default rates (Issler, et al., 2020). As Chapter 3 will discuss, declines in mortgage values could affect financial market participants, including banks that hold these mortgages on their balance sheets, investors in mortgage-backed securities, and government-sponsored enterprises (GSEs), primarily Fannie Mae and Freddie Mac, which guarantee the default risk of the mortgages they securitize (Ouazad and Kahn, 2019). Emerging evidence suggests that lenders are passing along riskier mortgages (Ouazad and Kahn) to the GSEs, in part, to remove risk from their own books (Keenan and Bradt, 2020). The federal guarantee of the GSEs suggests that U.S. taxpayers may ultimately be on the hook for prepayment and default risks associated with the impacts of physical risks on collateral values (Ouazad and Kahn, 2019; Keenan and Bradt, 2020).

Human Health and Labor Output

Human health is significantly exposed to climate-related physical risks. Health impacts from climate change include extreme heat exposure; degraded air quality; infectious, water- and vector-borne diseases; food contamination and declining access to nutritious foods; chronic physical and mental stress; and, physical injuries and mental distress from extreme events (Ebi, et al., 2018). Many of these health impacts and corresponding financial costs have been shown to disproportionately burden low-wage workers and historically marginalized populations (Schmeltz, et al., 2016; Wondmagegn, et al., 2019). Thus, mitigating climate

change would reduce economic burdens that amplify economic inequality. For instance, a decline in the use of fossil fuels will improve air quality, which would have a disproportionately positive impact in certain marginalized communities (Bullock, et al., 2018).

These impacts could also reduce labor capacity and productivity, which in turn could reduce the capacity of workers and employers to pay for healthcare services. Most critically, extreme heat is anticipated to greatly impact human health and lead to greater rates of premature mortality. From extreme heat alone, annual damages from premature death in 2090 were projected to be between $60 billion (2015) and $140 billion (EPA, 2017). States in the Southeast and Great Plains could see declines in labor capacity approaching 3 percent (Dunne, et al., 2013; Houser, et al., 2015); some locations in Florida and Texas could see a total loss in annual labor hours of 6 percent or more (Gordon, 2014; EPA, 2017). Six percent is the equivalent of losing two weeks of income a year. By 2090, total impacts from extreme heat attributed to climate change could result in more than 2 billion lost labor hours, corresponding to $160 billion (2015) in lost wages (Graff Zivin and Neidell, 2014; Hsiang, et al., 2017; EPA, 2017). Indeed, companies that rely on outdoor and manual labor may face physical risks from declining labor productivity and higher costs associated with workers' compensation, health insurance, and general liability insurance. They may also face pressure to increase wages to attract workers for such physically demanding employment (Day, et al., 2019). In cumulative terms, these emerging impacts are anticipated to disproportionately impact LMI and historical marginalized communities.

Finally, as the COVID-19 pandemic has made clear, healthcare and public health systems in the United States have limited excess capacity to treat patients during extreme events (Bein, et al., 2019). Such events could include, for example, events stemming from infectious diseases and tropical cyclones attributable, in part, to climate change (Wu, et al., 2016). Public health infrastructure in the United States and around the world has been affected by significant reductions of public investment in recent decades (Masters, et al., 2017). Unless this trend is reversed, the U.S. healthcare system may not be able to cope with the burdens from climate-related physical risk. For instance, healthcare facilities, networks and enterprises could face financial challenges associated with the exposure of highly vulnerable and aging populations subject to increasing climate-attributed stresses, such as extreme heat and infectious disease, and shocks, such as stronger hurricanes and wildfires (Desai, et al., 2019).

Supply and Demand Shifts

Climate change likely will further affect both supply and demand in the economy. For instance, demand for electricity for space cooling and water for irrigation may significantly increase. However, direct and indirect measures of demand may also decrease. There is little empirical research on the extent to which output per worker may decline and the extent to which wage pressure and financial burdens may be redistributed demographically. However, climate change—within the context of broader trends such as the aging of society, and income inequality—likely will put additional and disproportionate pressure

on consumers and taxpayers (Hallegatte and Rozenberg, 2017). In theory, with lower wages and greater fiscal and financial burdens, American consumers could have relatively less spending power to support existing demand for the financial services, tourism, and retail sectors, with implications for manufacturing and wholesale trades. In some cases, local demand may be affected by climate-driven migration that may lead to depopulation in high-risk areas (Hauer, 2017). In these scenarios, historically marginalized populations and frontline communities likely would disproportionately bear the economic burdens (Kim, et al., 2018; Siders, 2019).

Beyond consumption and demand effects, many sectors of the economy face direct physical risks to their primary production and distribution, as well as to their supply chains (Goldstein, et al., 2019). Many sectors have benefited in recent years from firms within the sector coordinating their operations and supply chains to make them more resilient to increases in extreme weather that routinely directly impact 70 percent of all economic sectors (Brusset and Bertrand, 2018). The greater the complexity within a supply chain, the greater the system's resilience to climate shocks likely will be (Lim-Camacho, et al., 2017). However, increased redundancy in supply chains can come with the cost of reduced efficiency. The degree of supply chain re-optimization needed to respond to climate risks remains subject to a great deal of uncertainty. As climate change impacts increase, consumers, producers, and suppliers across all economic sectors will need to develop ongoing intelligence about direct and indirect physical risks in order to advance the economy's resilience and foster disciplined risk-taking in consumption and production (Keenan, 2019).

Transition Risk

Transition risks arise from both uncertainties and substantive changes. They include market, credit, policy, legal, technological, and reputational risks. These transition risks range from the introduction of an explicit or implicit price on carbon to the economic obsolescence of entire asset classes because of changing consumer preferences. Transition risks may lead to economic losses for some, while at the same time yielding benefits for others. Transition risks may lead to both stranded capital, where asset-level capital is at-risk from devaluation, or stranded value, where the market-value of a project or firm is at-risk from devaluation or otherwise negatively discounted (NGFS, 2019a). In essence, transition risks arise when firms fail to prepare for or recognize broader market transitions.

In a speedy transition to a net-zero economy, fossil fuel industry assets might become stranded (Harvey, et al., 2018). To provide some context, 75 percent of total U.S. energy is derived from fossil fuels (EIA, 2020). In 2019, fossil fuels provided the energy for 62 percent of electricity generation and 95 percent of transportation (EIA). One estimate for stranded capital from fossil fuel assets suggests a potential global loss of wealth between $1 trillion and $4 trillion (Mercure, et al., 2018). In an alternative estimate, current stranded assets within fossil fuel companies range between $250 billion and $1.2 trillion—depending on how fossil fuel firms respond to global emissions reductions (IEA, 2020). Many of these

assets may or may not be fully depreciable given the significant uncertainty around public policies and consumer preferences concerning the timing, mode, depth, and cost-sharing of many energy transition scenarios (Kefford, et al., 2018).

In terms of stranded value, emerging evidence suggests that, in some cases, markets may already be pricing in transition risk. For example, a recent study suggests that uncertainty associated with policy risk is already penalizing oil companies that are investing in undeveloped fossil fuel reserves (Atanasova and Schwartz, 2019). Another study shows that, even with recent domestic policy support, market forces likely already have reduced domestic coal consumption past a point of no-return (Mendelevitch, et al., 2019). Between 2007 and 2017, total coal production in the United States declined by 32 percent, primarily because of persistently low natural gas prices (Morris, et al., 2020). Modeling of climate policy shows that risks to coal producers in the future will be even higher. One study suggests that a price of $25 per ton of CO_2 rising at 5 percent a year more than inflation could by 2030 reduce U.S. coal production to 77 percent below 2016 levels (Morris, et al.). Declines in coal may also negatively impact state and local tax and royalty revenue. Concerns over stranded capital in coal assets are already impacting the financing of assets, even in high-growth countries that have strategically planned to expand coal generation capacity (Ha-Duong, 2020).

Financial market participants are already looking for ways to manage transition risk in their investment portfolios. For example, recent research suggests that portfolios that over-weight "greener" firms will outperform during periods with negative climate news (Engle, et al., 2020). Institutional investors already appear to be screening potential investments for direct carbon emissions and demanding compensation for associated transition risks (Bolton and Kacperczyk, 2019). This demand likely stems from the anticipated impacts of transition risks across the economy. Investors likely will increase their efforts to identify which assets are unduly exposed to a collapse in asset values that could threaten the economic viability of entire asset classes (Carney, 2018).

As a subset of transition risk, technological risks also represent a challenge for financial and fiscal stability. A wide variety of new technologies are needed to advance net-zero energy production, distribution, storage, and utilization. Firms and public policies will inevitably seek to pick winners and losers among these technologies and among the users of these technologies (Zurich, 2018). The risk is that investments will be made in inferior technologies that either fail to achieve their stated level of performance or are surpassed by superior technologies before their full economic utilization or depreciation. The extent of the technological risk often depends on the speed and diffusion of inferior technologies. Ultimately, consumers' preferences for products and services of varying degrees of sustainability represents its own category of transition risks, whether it is meat consumption, gas powered vehicles, or even investment products.

By the same token, public policies that seek to advance specific technologies represent a policy risk if a technological beneficiary does not achieve the desired level of performance or economic return. Beyond misplaced technology preferences, policy risks may arise from a variety of legislative and administrative actions, or inactions, that fail to address the speed and depth of climate change. Risks for even the most well intended public policies, whether local sustainable investment protocols or federal tax policies, are defined by their distributional costs and benefits, timing, effectiveness, uncertainty, and continuity. Policy pathways could be classified along a continuum from smooth to disruptive. Disruptive policy pathways may be out of line with social momentum or technological capacity. A policy pathway may be disruptive because it is simply delayed too long or lacks the continuity to guide long-term capital investments. As Chapter 6 will discuss, poorly designed and poorly implemented policies can distort the allocation of capital across sectors and industries. In addition, a pathway may be disruptive because it leads to unmitigated sector-specific unemployment that is sensitive to the speed of energy transitions.

Current initiatives, such as the Inevitable Policy Response promulgated by the United Nations' Principles for Responsible Investment (PRI), have begun to provide a resource for financial markets to forecast short- to mid-term climate policies (PRI, 2019). Key policy domains include coal phase-outs; bans on internal combustion engine vehicles; carbon pricing; carbon capture and storage; net-zero power; energy efficiency; land use-based carbon management; and agricultural technologies and infrastructure policies. Each of these policies is evaluated based on institutional, political, and technological readiness, as well as metrics associated with social momentum and social equity (PRI). These are just a few of many metrics and models for evaluating policy risk that are discussed in more detail in Chapter 6.

Public and private sector actors also face a variety of climate-related legal risks, both physical and transition, from litigation and contract liability. As of the date of publication, more than 1,100 climate-related lawsuits have been filed in the United States (Sabin Center, 2020). The most high-profile litigation has centered on complaints advanced by state attorneys general for violations of state securities laws, among other allegations, against a fossil fuel legacy firm for its alleged failure to adequately disclose material climate-related risks to investors. In securities law, future legal risks likely will involve decisions about whether climate-related risk factors are material enough to require disclosure, as well as the adequacy of disclosures (Vizcarra, 2018; Vizcarra, 2020).

Finally, state and local governments have filed more than a dozen lawsuits under various tort theories, including state common law public nuisance claims, to recover climate-change related expenses from energy industry defendants. None of these lawsuits have ultimately satisfied the plaintiff's cause of action or theory of damages. However, a great deal of uncertainty is associated with an unbounded range of potential claimants and defendants. In such a mass tort scenario, federal legislation may be needed to organize claims and damage allocations, as with the tobacco litigation of the 1990s (Olszynski, et al., 2017).

Legal issues beyond tort and consumer protection claims may directly impact the financial economy. First, there are open questions about the extent to which officers, directors and other fiduciaries may be violating fiduciary duties by investing in, or failing to disinvest in, various carbon-intensive or otherwise highly exposed assets, companies, and industries (Gary, 2019). A second challenge arises from uncertain legal liability for public and private sector actors who fail to adequately disclose material physical risks on debt offerings and other contracts (Keenan, 2018). For public entities, a broader range of legal liabilities relate to limits on sovereign immunity arising from negligent mismanagement of physical risks (Klein, 2015). Finally, professionals such as, architects, engineers, and corporate directors face significant questions about the consideration of climate change risks and their duty of care (Hill and Martinez-Diaz, 2019).

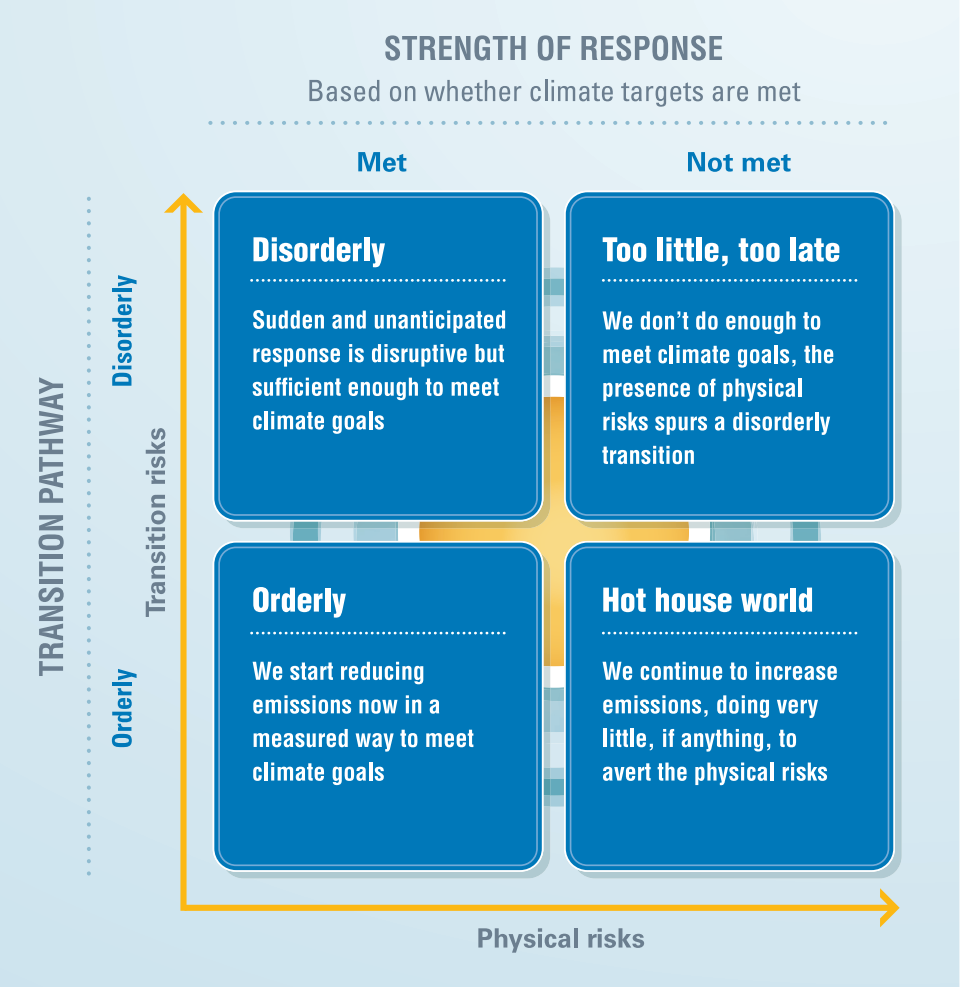
An additional technical challenge relates to the evidentiary application of attribution science to connect climate change with damage-specific events, as well as the causal relationships associated with demonstrating legal standing to bring claims (Marjanac and Patton, 2018). Overall, the accelerated pace of climate change is reorienting longstanding commercial relationships, memorialized in public and private law, faster than governing principles can be developed through appellate litigation. Additional legislation and regulation will ultimately be required to calibrate many facets of the law and the regulatory state—adding additional policy risk.

Integrating Physical and Transition Risk

While usually discussed as distinct concepts, physical and transition risk will not remain in neatly separated boxes in the real world. The two are likely to interact in complex ways. For example, dedicating more resources to accelerate the transition to net-zero energy generation could create trade-offs, diverting resources from climate adaptation measures, thereby amplifying vulnerability to physical risks. Conversely, adaptation investments that mitigate the exposure and sensitivity of assets without regard for carbon management may ultimately amplify transition risks. Importantly, the longer governments wait to adequately cut emissions, the more rapidly physical and transition risks are likely to increase in parallel. The physical impacts of climate change will intensify while the magnitude of the response needed to arrest further warming grows. The public and private sectors must simultaneously advance both climate mitigation and adaptation to effectively manage both physical and transition risks.

In other areas, such as real estate, assets may be devalued simultaneously as a function of both absolute losses from physical risks and from the transition risk of consumer preferences shifting away from "non-green" assets that lack sustainability and resilience. Even within sectors with high measures of physical or transition risks, organizational resilience and risk management may dictate a wide variation in climate-related risk to any given firm (S&P Global, 2019).

Figure 2.3: High-level Framework for the Scenario Analysis of Physical and Transition Risks



Source: NGFS (2019b)

Figure 2.3 highlights four high-level scenarios that may be useful to frame assumptions and parameters for future analysis of the adequacy of measures to address physical and transition risks. The two primary factors represented in this framework are the total amount of emissions reduction and the orderliness and continuity of any transitions (NGFS, 2019b). Understood along a continuum, these factors likely will shape emerging strategies for managing market, credit, policy, legal, technological, and reputational risks. The goal is for the public and private sectors to manage an orderly transition that also recognizes and internalizes physical risks. As the following chapters will discuss, understanding the various modes of the transmission of these physical and transition risks into the various markets, instruments and assets classes of the financial system is critical for understanding the parameters shaping future investment analysis and prudential oversight.

Chapter 3

Implications of Climate Change for the U.S. Financial System

As described in Chapter 2, climate-related physical and transition risks, if not well-managed, likely will materially impact the value of a wide range of assets. This chapter explains how those impacts may manifest throughout the financial system, first considering general implications and then covering risks to financial markets and institutions.

A Unique Challenge for Financial Stability

Our understanding of how climate change and societal responses to it will affect financial markets, institutions, and systems remains in its infancy. It is clear, however, that climate change presents a uniquely complex set of financial risks for three reasons. First, climate change will affect multiple sectors, geographies, and assets in the United States, sometimes simultaneously and within a short timeframe. This is no longer theoretical. For example, in a recent span of 24 months, the United States experienced several unprecedented extreme events. In 2017, for the first time in history, three Category 4 hurricanes made U.S. landfall in a single year, causing extensive damage to the Gulf Coast. In 2018, California experienced its deadliest and most destructive wildfire season in recorded history. And in the year through May 2019, the United States experienced its wettest 12 months on record, including devastating floods affecting 14 million people in the Midwest and South. In the future, such impacts could compound, magnifying economic and financial shocks.

Second, climate-related financial risks are large but remain uncertain because climate change is shifting fundamental environmental parameters, pushing planetary systems to new extremes. This is true for both acute and chronic physical risk. As a result, the climate in the future will fundamentally differ from today's climate. Traditional risk-modeling techniques, which rely heavily on historical data, will become increasingly unhelpful guides to the future. That presents a significant challenge to financial market participants and regulators, whose decisions hinge on having good information and data on which to ground their views about future conditions. Thus, society's ability to understand climate risk will require forward-looking analysis, which is still being developed (Barnett, et al., 2020).

Third, the impact of climate change on a wide range of variables involves tipping points and what economists call "discontinuities"—situations in which conditions can remain stable for a long time but then deteriorate sharply and suddenly. Studies suggest that variables such as economic growth, crop yields, and labor productivity deteriorate more quickly and suddenly once a certain threshold temperature has been crossed (Burke, et al., 2015). If these variables deteriorate non-linearly in response to climate change impacts, sudden and disorderly price adjustments in financial markets become more likely (Hong, et al., 2020). Breakthroughs affecting low-to-zero carbon technologies can also lead to discontinuities, and consumer preferences and energy consumption patterns can change unexpectedly and rapidly (Kuran & Sunstein, 1998).

Systemic Shocks

Because of their scale, breadth, and complexity, the impact of climate-related risks could be systemic. While no official definition of systemic financial risk exists under U.S. law, the most widely-accepted definitions contain several elements: (i) *shock amplification*, which refers to conditions in the financial system that allow a given shock to propagate widely, magnifying its disruptive effect; (ii) *disruption* or *impairment* of all or part of the financial system, meaning that portions of the system cease to effectively support economic activity; and (iii) *severe externalities*, meaning spillovers affect the real (non-financial) economy (Adrian, et al., 2014; IMF, BIS and FSB, 2009). Climate-change related risks can produce all three of the elements.

Systemic shocks are more likely when the prices of a wide variety of financial assets do not fully reflect climate-related physical and transition risks. Standard asset-pricing theory suggests that market participants will demand a premium to hold assets exposed to climate-related physical and transition risk. When those risks are not fully priced in, market participants will accumulate larger exposures to risky assets than would otherwise be desirable. A sudden revision of market participants' perceptions about climate risk could trigger a disorderly repricing of assets, which could have cascading effects on portfolios and balance sheets and, therefore, systemic implications for financial stability.

Evidence is accumulating that markets are pricing in climate-related risks imperfectly, and sometimes not at all. As the previous chapter explained, the U.S. property market is beginning to price in risk of sea level rise and climate-attributed flood risk—but unevenly. For example, one study found that investors purchasing U.S. rental properties are demanding risk premiums well aligned with scientific projections for homes exposed to sea level rise but people purchasing homes for primary occupancy, on the other hand, are less likely to do so (Bernstein, et al., 2019). Another study examined stock prices across multiple countries, including the United States, and found no association between current stock prices and measures of predicted changes in climate-related physical hazards, even after controlling for fundamentals and for countries' capacity to adapt to climate change (IMF, 2020).

An emerging body of research suggests that climate risk is currently underpriced in some markets, and that climate-exposed financial assets may be overvalued. Sudden and disruptive repricing is therefore possible should market participants revise their perceptions about

physical and transition risk. A variety of factors could trigger revised investor perceptions, including election outcomes, reports of technological breakthroughs that reduce the cost of zero-carbon technologies, new research findings about the speed and nature of physical climate impacts, and the occurrence of major catastrophes that raise awareness of new risks.

In addition, the fact that climate-related risks do not operate in isolation makes a systemic shock more likely. As Chapter 2 suggests, transition and physical risks could interact and compound the disruption either would exert on its own. In addition, climate-related risks could interact with existing, non-climate-related vulnerabilities in the financial system. For example, U.S. regulators have identified historically high levels of corporate leverage and the expansion of mortgage origination by nonbanks as existing risks to financial system stability (FSOC, 2019). Another, even more important, vulnerability is the likely legacy of the COVID-19 pandemic in the form of stressed financial-institution balance sheets, depleted household wealth, and growing business and government debt. Climate-related shocks could magnify any of these already serious vulnerabilities, increasing the probability of an overall shock with systemic implications.

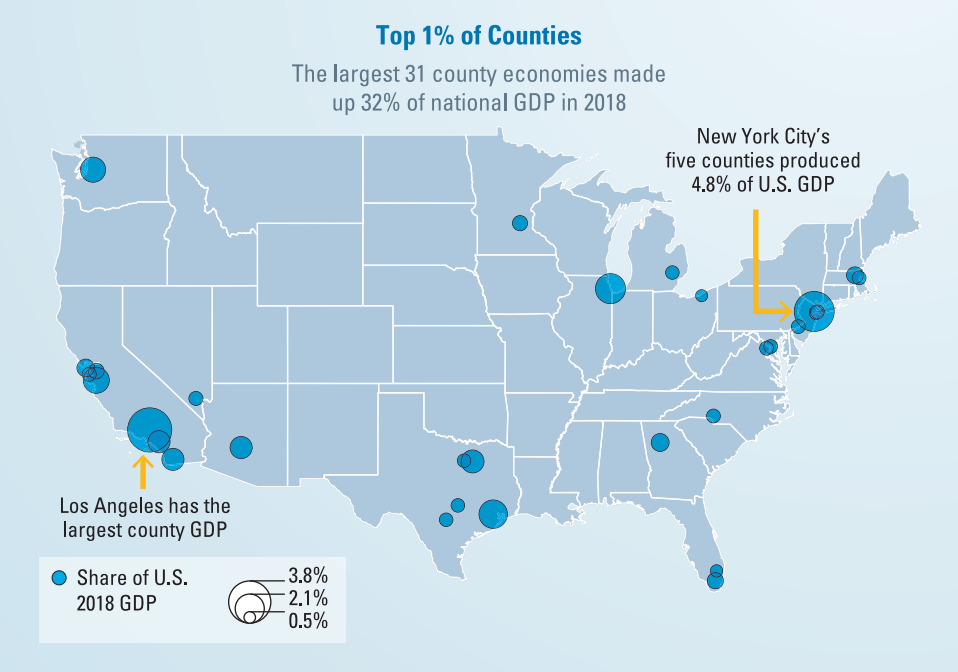
Sub-Systemic Shocks

Climate-related risks need not threaten the entire financial system to merit attention from financial regulators. Climate-related risks may well produce "sub-systemic" shocks, which are defined here as those that affect financial markets or institutions or a particular sector, asset class, or region, but without threatening the stability of the financial system as a whole. Such shocks are especially relevant for the United States, given its size and its financial system, which includes thousands of financial institutions, many regulated at the state level.

Sub-systemic shocks can result, for example, in businesses, farmers, and residents in particular communities losing access to hedging instruments, insurance, credit, and other critical financial services. In turn, that loss of access can result in business disruptions, lost income, and reduced household wealth. Over time, repeated sub-systemic shocks could lead to the gradual accumulation of stress in the U.S. financial system and to escalating economic and financial losses—a systemic crisis in slow motion.

The spatially-concentrated nature of economic activity in the United States compounds this risk. As shown in Figure 3.1, in 2018, just 31 counties—accounting for 1 percent of all counties—were responsible for generating one third of U.S. gross domestic product (GDP) (Tartar and Pickert, 2019). A majority of those counties are located along coastlines and are exposed to physical climate risk. Depending on how interrelated physical and transition risks become, economic activity in some of those counties could be adversely impacted both by transition and physical risk. Multiple shocks affecting several of those economic hubs over a short time horizon—a more intense version of what the country experienced in 2017-19, for instance—could cumulatively translate into an economic and financial shock with nationwide consequences.

Figure 3.1: Spatial Concentration of Gross Domestic Product



Source: Adapted from Bloomberg (2019); Bureau of Economic Analysis (2020)

Risks to Financial Market Operation

Climate-related risks may affect the functioning of markets essential for economic activity. This could happen through liquidity disruptions and through disruptions to financial market utilities.

Liquidity Disruptions

To function properly, financial markets require adequate liquidity. However, liquidity can deteriorate very quickly during shocks, for example when concerns about counterparty risk spike, or when financial intermediaries are unable or unwilling to perform certain functions. For example, U.S. issuance of commercial paper maturing beyond one week seized up in March 2020 during the COVID-19 pandemic, as did primary- and secondary-market liquidity for financial and nonfinancial commercial paper. This occurred partly because prime money market funds, anticipating investor outflows, rushed to raise cash and build liquidity buffers by selling commercial paper. Also, dealer banks were reportedly less willing to intermediate, as they faced balance sheet and risk-limit constraints (IMF, 2020). Intermediation difficulties were also reported in the municipal bond market. Dealers, faced with large outflows from municipal bond funds, could not warehouse the surging supply of bonds. Conditions eased only after the Federal Reserve injected liquidity into these markets through large purchases of the relevant assets.

A confluence of physical and transition risks in a short time could plausibly cause liquidity problems in key markets. For example, a combination of highly destructive, climate-related extreme events affecting key economic hubs, in the context of already-stressed balance sheets and historically high levels of corporate and municipal debt, could trigger widespread concern about creditworthiness across multiple sectors and regions. In turn, that could lead to a sudden spike in risk aversion, pushing investors to scramble for cash by selling commercial paper and rushing out of certain bond funds—causing liquidity shortages and intermediation difficulties.

A similar scenario is plausible in futures markets. A combination of slow-onset and sudden extreme weather events in major agricultural states, for example, could lead to high volatility in certain agricultural commodity prices. Commodity prices can become especially volatile when storage facilities are damaged or storage capacity is otherwise constrained, forcing contracting parties supplying the physical commodity to incur additional costs. High volatility, in turn, could result in calls for variation-margin payments to clearinghouses and to greater pressure on short-term funding markets at the same time as other institutions, such as insurers and reinsurers, may be tapping the markets to fund large payouts related to the same extreme weather events. The result could be a liquidity crunch that temporarily interferes with the smooth functioning of the commodity futures market. Transition risk could plausibly cause similar disruptions, for example with challenges to liquidity or energy futures markets.

Disruptions to Financial Market Utilities

Financial market utilities (FMUs) transfer, clear, or settle payments, securities, commodities, or other financial transactions among financial institutions.

The CFTC is primarily concerned with commodities and derivatives clearinghouses (otherwise known as designated clearing organizations, or DCOs), futures commission merchants, swap dealers, and major swap participants. Some DCOs are so critical that the Financial Stability Oversight Council has designated them as systemically important, which means that their failure "could create or increase the risk of significant liquidity or credit problems spreading among financial institutions or markets and thereby threaten the stability of the U.S. financial system" (Agnese, et al., 2017, p. 51).[1]

The CFTC has primary jurisdiction over two of the eight designated entities, the Chicago Mercantile Exchange (the CME Group) and ICE Clear Credit LLC. The CME Group, through its U.S. clearing division, is one of the largest central counterparty clearing services providers in the world. It clears all contracts traded on the designated contract markets owned by CME Group, Inc., which includes the largest and most liquid futures contracts

[1] *Currently, eight clearing organizations have been designated as systemically important: (i) the Clearing House Payments Company L.L.C. on the basis of its role as operator of the Clearing House Interbank Payments System; (ii) CLS Bank International; (iii) Chicago Mercantile Exchange, Inc.; (iv) The Depository Trust Company; (v) Fixed Income Clearing Corporation; (vi) ICE Clear Credit LLC; (viii) National Securities Clearing Corporation; and, (viii) The Options Clearing Corporation.*

based on the S&P 500 Index, Eurodollars, U.S. Treasuries, and energy products, as well as interest rate swaps. Significant disruption of its operations would cause liquidity to dry up in futures and options markets, which could threaten the stability of the U.S. financial system (Treasury, 2017). ICE Clear Credit clears a majority of the credit default swap (CDS) products in the United States that are eligible for clearing by a central counterparty. Its clearing members include global systemically important financial institutions. Disruption of its operations could lead to cascading defaults, which could create instability in U.S. CDS and securities markets (Treasury, 2017).

Climate-related disasters, such as storms, floods, or damaging winds, could disrupt the operations of FMUs, perhaps even systemically important ones, depending on the location and climate-vulnerability of the FMU's physical infrastructure. Prolonged disruptions could have severe consequences for the markets they serve, including paralysis. While markets have yet to experience major FMU disruptions, smaller episodes suggest this risk must be considered. In 2012, for example, Superstorm Sandy flooded a vault of the Depository Trust and Clearing Corporation (DTCC), an important clearing and settlement company with three subsidiaries designated by regulators as systemically important FMUs. The flood damaged or destroyed 1.7 million stock and bond certificates, as well as millions of other documents. It took the company weeks to recover, restore, and reconcile the documents. The company was unable to begin even a preliminary assessment of the damage for two weeks, until water had been pumped out of its vault (DTCC, 2014).

Risks to Financial Institutions

In addition to affecting financial market functioning, climate-related risks may also affect financial institutions, potentially including systemically important ones. Three sets of questions are important here: Which combinations of assets could be affected by climate-related risks, by how much, and how quickly? Who holds those assets, and what is their ability to absorb the losses? And, to what extent are losses mitigated by public and private shock absorbers?

Which combinations of financial assets are affected, by how much, and how quickly?

As explained in Chapter 2, climate change will likely present a material risk to certain companies and asset classes. But the extent to which the value of those securities and assets is affected, and in what combination, also will have important implications for the holders of those securities and for financial markets more generally. As shown in Table 3.1, the financial assets most likely to be impacted fall in several categories—those tied to: (i) real property; (ii) infrastructure; (iii) companies whose business is affected by climate-related risks; (iv) coverage providers (namely insurers and reinsurers); and, (v) government revenue.

Key uncertainties include the size and frequency of the losses and the potential for simultaneous losses across different asset classes. In the case of physical risk, for example,

Table 3.1: Categories of Assets Exposed to Climate Change Impacts	
Categories	**Examples**
Financial assets directly tied to real property	• Commercial mortgage-backed securities (CMBS) • Commercial real estate (CRE) bank loans • Government-sponsored enterprise (GSE) Credit Risk Transfer securities • Real Estate Investment Trusts (REITs) • Residential mortgage-backed securities (RMBS) • Residential mortgages
Financial assets tied to infrastructure	• Debt and equities of power and water utilities and communications companies • Debt and equities of public and private transportation infrastructure
Financial assets tied to companies with businesses models or operations likely to be impacted by physical or transition risk	Equities and debt of firms in the following sectors: • Agriculture • Airlines and the broader transportation sector • Automobiles • Cement, steel, chemicals, plastics • Energy, including coal, oil, and gas production • Hospitality • Metals and mining • Power generation • Service and infrastructure providers to oil and gas • Tourism
Financial assets tied to insurance coverage providers	• Insurance and reinsurance company debt and equities • Insurance linked securities (ILS)
Financial assets tied to streams of government revenue	• Municipal bonds • Sovereign bonds

major flooding of residential and commercial property over a large region could result, in a short time, in rising mortgage delinquency and prepayment rates and falling values of residential mortgage-backed securities, securitized commercial real estate (CRE) loans, the bonds of affected municipalities, and the stock of insurance companies (if insurance companies must make large payouts for flooded commercial property). Importantly, the extent of the climate-related damage and the financial losses associated with them can be reduced through investments in resilience, business continuity planning, and effective climate risk management more generally.

In the case of transition risk, a sudden adoption of ambitious climate policy—or, more likely, a sudden shift in perceptions about the likelihood of a major policy change—aimed at limiting greenhouse gas emissions, even if the policy is phased in gradually, could impact the debt and equity values, investment, and payrolls of companies across several sectors, assuming that the costs of compliance are not fully passed through to consumers. Aside from companies in the oil, gas, and coal mining business, the shock could affect sectors including electric and gas utilities, motor vehicles and parts, and transportation and warehousing (Jorgenson, et al., 2018). On the other hand, investments that incorporate climate considerations, such as sustainable investments, can also provide financial upside and help hedge against climate-related losses.

Who holds the assets, and what is their ability to absorb the losses?

How climate-related losses impact financial markets and institutions depends in part on which entities hold affected assets, the entities' risk management capability, and their loss-absorbing capacity. A nuanced understanding of different types of financial institutions is required. The degree to which climate risks become material for specific banks and other firms will depend in part on those institutions' capability of measuring and managing those risks. As Chapter 5 describes, financial institutions can integrate climate into their risk management framework in various ways. Subsequent chapters also describe how tools such as scenario planning and climate stress testing can help regulators and financial institutions understand whether and how climate risk may constitute material risk for particular firms.

Credit-Providing Institutions. Commercial banks and other credit-providing institutions lend to entities in locations and sectors that may experience climate-related impacts. Banks could both suffer losses from impaired loans and be left less able to provide credit to affected entities or even entire sectors.

In the case of transition risk, banks that lend to companies in carbon-intensive sectors may have some time to course-correct when facing policy or technological change that effectively increases the price of carbon and limits their clients' financial prospects. Average commercial and industrial loans in the United States typically have a maturity of one-to-three years. That gives banks frequent opportunities to modify loan terms and conditions and incorporate newly understood credit risks. In extreme circumstances, banks can refuse to roll over loans if they believe a company remains at high risk from sudden shifts in climate policy, technology, and changes in consumer demand.

Over the medium and long-run, however, the risk for banks would grow if they stopped lending to carbon-intensive companies and sectors but could not replace these loans with enough new credits to companies better able to adapt to higher carbon asset risk. If a bank, even a large one, was unable to adapt quickly enough, its financial soundness could be at risk. Certain policy paths—particularly major shifts in climate policy, or a shift in perceptions about the likelihood of such a policy change—could trigger an abrupt downturn in revenues and valuations for companies in carbon-intensive sectors, possibly

forcing banks to recognize credit losses on their loans and marked-to-market losses on their securities holdings. It is worth noting that several large U.S. banks have set sizeable "green" or "sustainable" finance goals, which suggests they are confident in their capacity to expand that side of their business.

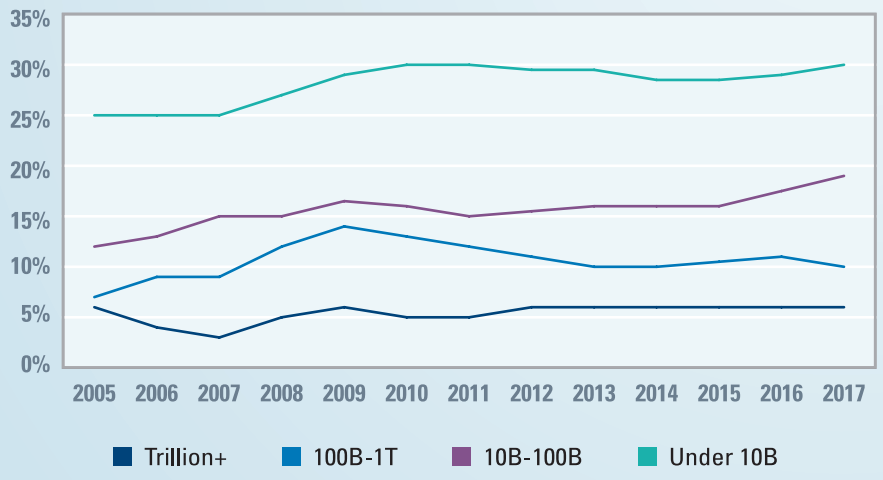
In the case of physical risk, it is worth distinguishing between large, well-diversified banks and smaller institutions that serve particular regions or communities. In general, the largest U.S. banks are relatively well positioned to cope with sudden climate-related extreme events, such as storms, floods, and wildfires. Large credit providers' portfolios typically are geographically and sectorally diversified. Research suggests that bigger banks may be better able to offset temporary regional losses from natural disasters with earnings from other regions (Landon-Lane, et al., 2011). Large banks also are more resilient to particular climate-related extreme events than smaller banks because they have more diversified business models and are required by regulators to hold more capital relative to their assets.

However, large banks are not immune to chronic physical risks, such as prolonged drought and sea-level rise, which may materialize over multiple years or even multiple decades, and they are not immune to major disasters of increasing frequency and pervasiveness. Both these risks are more likely to simultaneously impact multiple sectors and regions, increasing credit risk across many borrowers. For example, in 2017, nine major international banks with combined assets of more than $10 trillion, including one large U.S. bank, conducted a scenario analysis to assess how water stress might affect creditworthiness among a sample of their borrowers (UNEP FI, 2017). The banks undertook the exercise voluntarily to help them integrate and strengthen climate risk management.

The exercise showed that extreme droughts would increase loan default losses 10-fold for certain bank portfolios. Even under milder climate change scenarios, most companies in the analyzed portfolios experienced credit downgrades. The most affected sectors were water supply, agriculture, and in certain countries, power generation. In several cases, most of the financial losses came from slow-onset, chronic impacts such as drought, not from sudden extreme events. A key question for large banks remains not only how to manage these longer-term physical risks, but also how to manage them in a context of potentially growing transition risk.

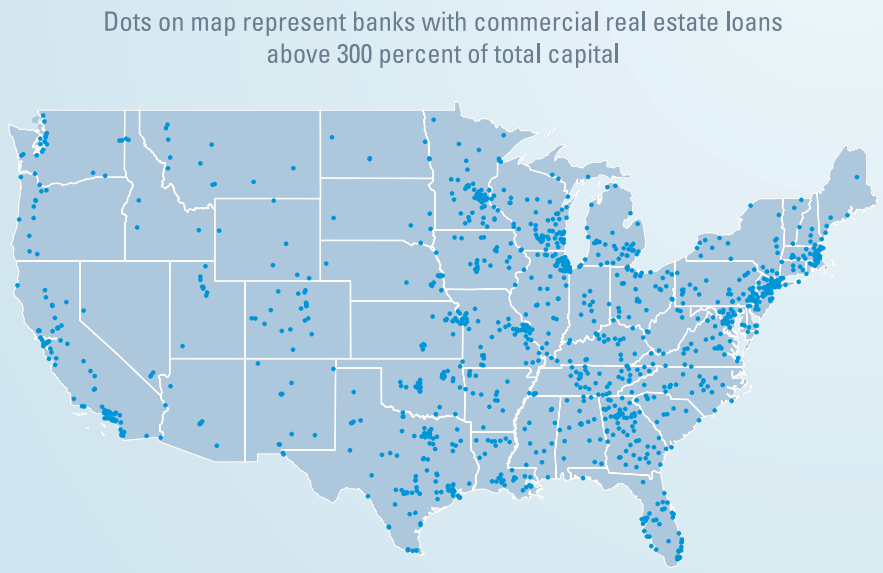
Regional and community banks, in contrast, are more vulnerable to regionally concentrated physical risk, including to sudden extreme events. In 2019, community banks held 30 percent of all CRE loans, worth about $700 billion (FDIC, 2019). These banks' property loans tend to be more geographically concentrated than the loans of larger banks. In addition, CRE loans constitute a much larger share—nearly a third—of the loan books of small banks, as shown in Figure 3.2. In contrast, CRE loans represent only a small fraction (just over 5 percent) of the total loans of the largest banks. For this reason, climate-related shocks that affect commercial property in a particular region can take a much heavier toll on small institutions, which tend to be regional and community banks, than on banks with nationwide or global balance sheets. Figure 3.3 highlights the regional nature of depository banks' exposure to commercial real estate lending.

Figure 3.2: Commercial Real Estate Mortgages as a Percent (%) of Total Loans, by Bank Size Measured in Assets



Source: Adapted from Yardi Matrix, based on data from BankRegData

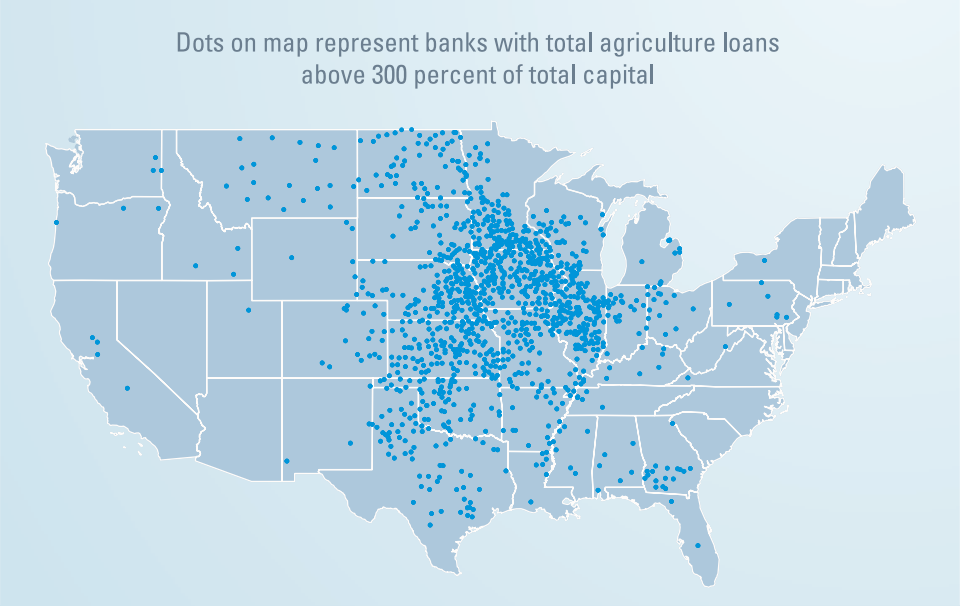
Figure 3.3: Regional Exposure to Commercial Real Estate Lending



Source: Adapted from FDIC (2019)

Similarly, small banks in the Midwest, in particular, hold proportionately more of certain types of agricultural loans that could be affected by climate impacts. Flooding and extreme heat reduce crop yields and disrupt agricultural production. For example, following severe flooding

Figure 3.4: Regional Exposure to Agricultural Lending



Source: Adapted from FDIC (2019)

in the spring of 2019, bankers lending in the Midwest reported to the Federal Reserve Bank of Chicago that about 70 percent of their borrowers were at least moderately affected by extreme weather events in the first half of the year (Oppedahl, 2019). At the same time, the portion of the region's agricultural loan portfolios reported as having "major" or "severe" repayment problems hit its highest level in 20 years (Oppedahl).

Agricultural banks—those whose combined agricultural production and farmland loans account for at least a quarter of total loans—hold nearly half of all agricultural loans originated by U.S. commercial banks (Humston, 2019). Most of those banks are in the Midwest, as shown in Figure 3.4. Many agricultural banks are small and highly exposed to impacts that reduce farmers' ability to service their debts, including climate-exacerbated extreme weather events. Indeed, more than 70 percent of nonperforming agriculture loans in the Midwest sit on the balance sheets of banks with less than $10 billion in assets (Tariq and Duren, 2019). Should agricultural banks become credit-stressed, farmers could lose access to affordable credit, making it more difficult for them to recover from climate-related shocks.

Institutions Holding Climate-Impacted Assets. This category includes a diverse range of financial institutions, including banks, pension funds, endowments, mutual funds, and insurance companies. These institutions operate along a wide spectrum of investment horizons and risk appetites, but prudent management of climate risk is essential for all. Most of them hold assets that may be affected—and in some cases are already being affected—by transition or physical risk. Ineffective management of these risks could lead to large financial losses, which in turn could trigger asset fire sales and elevated

counterparty risk. These events can channel financial contagion. Also, because climate risk is expected to increase over time, asset holders with longer asset-liability structures are more exposed to climate risk.

Commercial mortgage-backed securities (CMBS) offer one example. CMBS are made up of commercial mortgages pooled together and secured by commercial property, such as hotels, office and retail buildings, and warehouses. About half a trillion dollars of CMBS were outstanding as of 2019 (MBA, 2019), much of it held by institutional investors. Some of these loans, and the property that secures them, are at risk from flooding, wildfires, windstorms, storm surge, and sea level rise. As of March 2019, properties in New York, Houston, and Miami—cities that are highly vulnerable to climate change-exacerbated flooding because of sea-level rise and more intense storms—alone made up one-fifth of CMBS properties by market value in the Bloomberg Barclays Aggregate Index (BII, 2019).

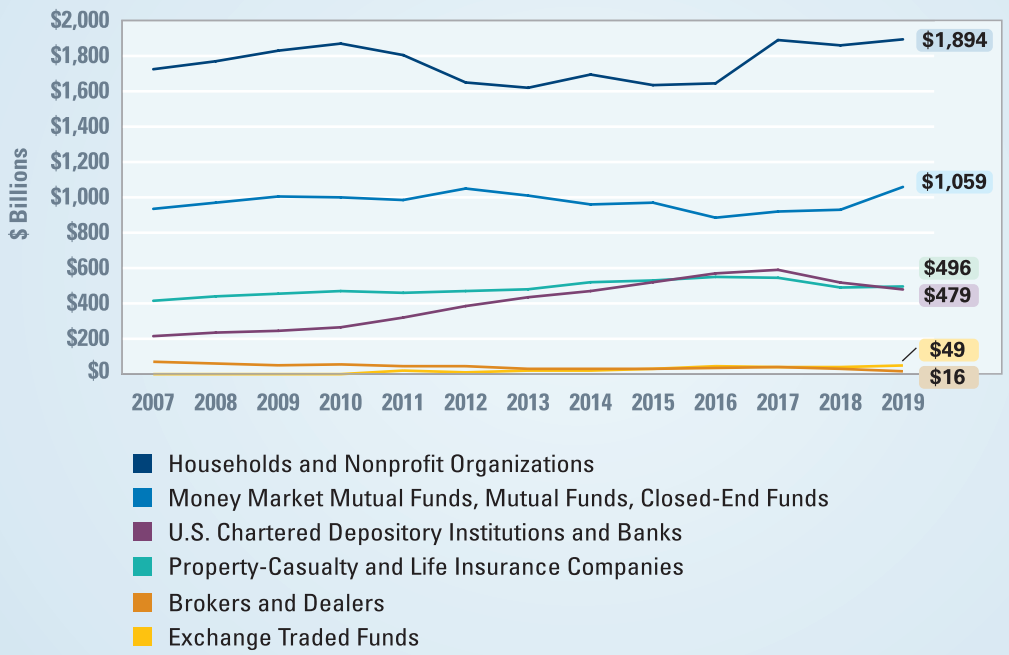
The risk likely will rise. One analysis estimated that about 6 percent of the properties in the CMBS market lie in Federal Emergency Management Agency (FEMA) flood zones, which are at elevated risk of inundation (BII, 2019). Another recent study identified 2,000 CMBS loans, worth more than $56 billion, that are exposed to climate change-exacerbated flooding along the East and West coasts (Morgan Stanley, 2019). Alarmingly, more than half of that exposure is estimated to lie outside FEMA flood zones. That means those properties are at higher risk of being underinsured, and therefore the loans attached to them are at higher risk of impairment, with increased risk for the value of the related CMBS.

Another example involves the $3.8 trillion municipal bond market, made up of debt issued by U.S. municipalities. It provides crucial financing to local governments, including for infrastructure (MSRB, 2019). As shown in Figure 3.5, mutual funds, banks, and insurance companies hold a majority—about 55 percent—of municipal bonds, with households and non-profit organizations holding most of the rest.

Hurricanes, floods, and other disasters are already affecting the economies of issuing municipalities, and that risk is expected to grow. One analysis calculated that within a decade, if significant climate action is not taken, more than 15 percent of the current S&P National Municipal Bond Index by market value will be issued by cities suffering likely yearly economic losses of 0.5 percent to 1.0 percent of GDP. By the end of the century, close to 40 percent of the index would be issued by cities facing 3 percent or more of yearly GDP losses because of climate-related impacts (BII, 2019). Also, climate impacts could be even more devastating to municipalities in the aftermath of the COVID-19 pandemic, which likely will weaken the fiscal condition of many state and local governments. Climate-related losses could impair municipalities' ability to service their obligations and lead to downgrades and eventually defaults and losses for municipal debt holders.

Spillover effects that undermine local industries and economic activity could also affect municipal revenue. For example, a climate-related disaster could lead businesses, workers, and residents to relocate permanently out of a highly affected area, resulting in lower economic activity, falling property prices, and declining real estate taxes. Climate change

Figure 3.5: Municipal Bond Holdings, by Type of Holder



Source: Based on data from Federal Reserve Board Financial Accounts of the U.S. (2019)

can also damage the economic base in locations where, for example, fish have moved to other areas because of warming seas, or where waterfront tourism is ruined by algae growth. These impacts would affect the creditworthiness of municipalities, particularly where tax revenue sources are not sufficiently diversified.

Transition risk could affect the municipal bond market as well. Unless state and local governments in areas that mine coal and extract oil and gas succeed in rebasing their economies, shifts away from the use of fossil fuels could result in falling royalties and taxes. Some municipalities depend on energy revenues for up to half of their total tax revenue. Revenue losses could cause fiscal stress and, eventually, municipal bond downgrades (Morris, et al., 2019; Morris, 2016). Although regulations require disclosure of municipalities' fiscal risks, disclosure of climate-related risks by municipalities remains minimal, as discussed in Chapter 7, exacerbating risks to municipal bond holders (Morris, et al., 2019).

To what extent are losses mitigated by public and private shock absorbers?

Whether and how financial institutions incur destabilizing losses because of climate risks depends crucially on the presence of shock absorbers, namely private insurance and reinsurance. In addition, the federal government's assistance to people and businesses during extreme events plays a crucial role in directly mitigating risks for those who are impacted, and indirectly in terms of how risks are transmitted across the financial system.

Evidence on the aftermath of disasters in the United States illustrates the importance of these shock absorbers in reducing potential losses to financial institutions. After Hurricane Katrina devastated parts of the Gulf Coast in 2005, for example, household debt *declined* because homeowners used large government flood-insurance payouts to pay off mortgages (Gallagher and Hartley, 2015). Similarly, a study showed Hurricane Harvey did not hurt consumers' access to credit, thanks in large measure to public and private shock absorbers, including FEMA assistance, Small Business Administration disaster loans, auto and property and casualty insurance payouts, and aid from the National Flood Insurance Program (NFIP) (Hartley, et al., 2019). Also, the National Crop Insurance Program was an important source of support to farmers in the Midwest following the catastrophic floods of 2019 (USDA, 2019). As long as these mechanisms continue to cushion the losses, the financial system will be at least partially shielded from climate-related shocks.

However, these shock absorbers should not be taken for granted. As past disasters have repeatedly demonstrated, private insurers often raise premiums in the aftermath of major events to ensure that they have sufficient reserves to cover future losses. Insurers may also exclude coverage for risks that are too large to cover even at a higher price. In some cases, insurers may exit a state, regional, or national market altogether. For example, home insurers left the home flood insurance market decades ago.

State legislatures and state regulators, when they have the authority, may limit premium hikes or compel insurers to provide certain levels of coverage. This has been the case in states such as Florida and California. But insurers can decide to exit markets if the premium limits or the coverage requirements mean they would not be able to cover their losses. Fundamentally, if the risk is too high for private insurers, the risk may ultimately be left with the property owner, the government, or both.

Climate change can cause insurance companies to fail. After the catastrophic 2018 Camp Fire in California, for example, a medium-sized insurer that had written many of its policies to cover fire had to be taken over by the California Department of Insurance (Koren, 2018). This danger could be exacerbated if private insurers underestimate the probable maximum losses they are insuring because their models do not fully capture long-term climate trends (DNB, 2017). Insurers typically provide one-year policies, and their underwriting decisions tend to be made using retrospective models with short time horizons. Thus, they, their reinsurers, and their regulators could neglect to account for climate change-related shifts in the frequency or intensity of catastrophic events that unfold over multiple years or decades.

Another challenge is that shock absorbers may themselves exacerbate risk by creating moral hazard. For example, the NFIP, which is the principal mechanism for providing residential flood insurance in the United States, subsidizes the insurance premiums of some properties, typically those in the riskiest areas. This feature effectively promotes excessive risk-taking in areas most exposed to flooding, inundation from sea level rise, and extreme precipitation

events (Kousky, 2018). The implications of this moral hazard range widely from encouraging continuing development of residential property in risky areas to local governments' continued reliance on an unsustainable property tax base. Additionally, not enough attention is being paid to long-term solutions, such as relocation and investing in long-term resilience measures (Hill and Martinez-Diaz, 2019). This moral hazard is not unique to insurers—the demonstrated willingness of governments to bail out financial institutions could create an incentive for them to mismanage climate risk.

Finally, a critical question is whether federal insurance and other government backstops can in the longer-term sustain significantly higher claims than they were designed to meet. For example, a 2019 analysis by the U.S. Department of Agriculture's Economic Research Service found that under different emissions and agricultural adaptation scenarios, the cost of the Federal Crop Insurance Program could increase by 3.5 percent to as high as 37 percent by 2080 (Crane-Droesch, et al., 2019).

Another example of a government shock absorber is the government-sponsored entities (GSEs), the Federal National Mortgage Association (Fannie Mae) and the Federal Home Loan Mortgage Corporation (Freddie Mac). Congress created the GSEs to make mortgages more available by enhancing the liquidity and stability of the U.S. secondary mortgage market. The GSEs were endowed with certain competitive advantages which, taken together, conveyed an implicit government guarantee on their financial obligations. After the 2008 financial crisis, the GSEs began transferring a meaningful portion of this credit risk to the private market via Credit Risk Transfer securities, which are purchased by hedge funds, money managers, Real Estate Investment Trusts (REITs), insurance companies and pension funds, though the GSEs retain considerable risk on their own balance sheets.

As major holders of mortgages and originators of residential mortgage-backed securities, the GSEs are exposed to physical climate risk affecting property, particularly flood risk. Because Fannie Mae and Freddie Mac are limited by rules governing how they underwrite mortgages, they may have limited room to screen for and manage climate risk (Ouazad and Kahn, 2019). In addition, some of this opaque risk could be transferred to other parts of the financial system through the GSEs' sales of Credit Risk Transfer securities. Ensuring that the GSEs are effectively measuring, monitoring, and managing climate risk will be imperative for their continued ability to enhance the stability of the U.S. mortgage market.

The limitations of government shock absorbers will be an especially pressing issue in the face of the enormous fiscal burdens from the COVID-19 pandemic. Responding to the pandemic has already resulted in federal debt levels not seen since World War II. If, for any of the reasons cited above, investors lost confidence that public and private shock absorbers would continue absorbing climate-related losses to the extent that they have, fear in financial markets could trigger a disorderly adjustment of prices in one or more asset classes.

Chapter 4

Existing Authorities and Recommendations for Financial Regulators

In the face of climate change, U.S. financial regulators must ensure that emerging risks are identified, measured, and effectively managed before they result in systemic or sub-systemic financial shocks.[2] This chapter explains how financial regulators should undertake this task. It also provides a high-level review of the authorities available to them under existing legislation and assesses the extent to which these authorities are sufficient to start addressing climate risk immediately. Finally, the chapter provides recommended actions that financial regulators can take to better protect the U.S. financial system from climate risk.

Five Functions of U.S. Financial Regulators

Regulators, in an ideal world, should be able to perform five important functions to address climate-related risks. These functions are consistent with how regulators manage more traditional risks to the financial system, such as credit, market, and operational risk. The five functions are:

Identify and provide oversight of physical and transition risk at a systemic level. Regulators should be able to monitor and assess how climate risk is affecting and could affect the financial system. That includes impacts on the functioning of financial markets and systemically important bank and nonbank financial institutions, impacts that cut across multiple asset classes and markets, and potential channels for financial contagion and shock magnification. Regulators should also be able to monitor "sub-systemic" shocks to parts of the financial system that serve particular sectors or regions of the country. This should

[2] *As explained in Chapter 3, "sub-systemic" shocks are those that affect financial markets or institutions in a particular sector, asset class, or region of the country, but without threatening the stability of the financial system as a whole.*

include institutions that fall under the threshold of "systemically important" but may be affected by sub-systemic shocks or more generally by the migration, motivated by climate risk, of financial activity from one part of the financial system to another.

Ensure that financial institutions, dealers, and other key market actors can monitor and manage climate risks. Financial regulators should have confidence that the entities they supervise have mechanisms and capabilities to manage climate risk effectively. These include, for example, effective governance arrangements, managerial incentives, risk identification protocols, and risk modeling and risk quantification tools and methods. Regulators should also encourage market participants to build capacity, develop data and tools, and share good practices.

Ensure that financial institutions, dealers, and other key market actors have the capacity to absorb climate-related financial impacts without causing system-wide or regional disruptions. Regulators should be confident that key market participants can cope with climate-related impacts such as credit, mark-to-market, and underwriting losses.

Ensure that investors, customers, and counterparties have adequate information to understand material climate risk. Publicly traded companies, entities registered with the CFTC and other regulators, and financial institutions should disclose information about material climate-related risks in an adequate and timely manner.

Identify and address climate-related operational vulnerabilities in financial market utilities (FMUs) and critical service providers. Financial regulators should have confidence that FMUs have adequately assessed their vulnerability to physical climate risk and have adequate contingency protocols, business continuity measures, and redundancies to ensure operational resilience in the face of a range of extreme climate events.

Existing Authorities and Practices

To what extent are U.S. regulators able to fulfill the roles identified above? Existing legislation, in general, provides U.S. financial regulators with broad and flexible authorities to perform the key functions outlined above. However, regulators are not fully utilizing their authorities and tools to effectively monitor and manage climate risk. Further rulemaking, and in some cases legislation, may be necessary to ensure a coordinated national response.

Systemic Risk Oversight

Regulators have significant, flexible authority to monitor and manage system-wide risk. The Financial Stability Oversight Council (FSOC)—created by the 2010 Dodd-Frank Wall Street Reform and Consumer Protection Act (DFA)—is charged with identifying risks and emerging threats to the financial stability of the United States, including those "that could arise outside the financial services marketplace" (DFA, 2010, Section 112). To that end, the FSOC is responsible for monitoring the financial services marketplace to identify

potential threats to financial stability, identifying gaps in regulation that could pose risks to financial stability, and facilitating information sharing and coordination among the FSOC member agencies and other federal and state agencies on rulemaking and examinations (DFA, 2010, Section 112), among other things. The CFTC is a voting member of the FSOC.

The FSOC is authorized to determine that a nonbank financial institution should be supervised by the Board of Governors of the Federal Reserve and subject to prudential standards (DFA, 2010, Section 113). It can make this determination if it judges that the institution, because of its nature, scope, size, scale, concentration, interconnectedness, mix of activities, or "any other risk-related factors that the Council deems appropriate" could pose a threat to financial stability (DFA, 2010, Section 113). (So far, FSOC has made four such determinations; all four designations have since been rescinded, three by the Council itself, and one by a federal court.) The FSOC can also recommend to the Board of Governors of the Federal Reserve—in the case of nonbank financial companies supervised by the Board of Governors and large, interconnected bank holding companies—that prudential standards and reporting and disclosure requirements be made "more stringent" than those applicable to other institutions that do not present similar risks to financial stability (DFA, 2010, Section 115).

The FSOC is supported by the Office of Financial Research (OFR) at the U.S. Department of the Treasury. The OFR is charged with performing long-term research and developing tools for risk measurement and monitoring (DFA, 2010, Section 153).

The Dodd-Frank Act also created the Federal Insurance Office (FIO) of the Department of Treasury, which is charged with monitoring "all aspects of the insurance industry, including identifying issues or gaps in the regulation of insurers that could contribute to a systemic crisis in the insurance industry or the U.S. financial system" (DFA, 2010, Section 502). The FIO can also recommend to the FSOC that it designate an insurer as an entity subject to regulation by the Board of Governors of the Federal Reserve.

Risk Management

Under existing authorities, regulators have wide latitude to help ensure that financial institutions, dealers, and other key market participants are identifying and managing risk effectively, including in the context of the five functions mentioned above.

Banks and nonbank financial companies. Regulators enjoy broad authority to prudentially supervise and regulate banks and nonbank financial companies.

Under the Dodd-Frank Act, regulators can prescribe more stringent prudential standards based on the riskiness, complexity, size and "any other risk-related factors the Board of Governors deems appropriate" in the case of nonbank financial companies supervised by the Federal Reserve and for bank holding companies of a certain size (DFA, 2010, Section 165). Those prudential standards may include enhanced risk-based capital requirements and

leverage limits, liquidity requirements, overall risk management requirements, concentration limits, contingent capital requirements, and "such other prudential standards as the Board of Governors [of the Federal Reserve]…determines are appropriate" (DFA, 2010, Section 165). The Federal Reserve can supervise bank and nonbank financial firms' risk management frameworks, including requiring that firms establish risk committees to ensure that corporate managers appropriately govern risk, that firms use enterprise-wide risk management practices, and that firms clearly define oversight responsibilities in their boards of directors.

One important supervisory and regulatory tool is stress testing. Within its existing authorities, the Federal Reserve stress tests large bank holding companies periodically through its Comprehensive Capital Analysis and Review (CCAR). The CCAR's goal is to ensure that financial institutions have forward-looking capital planning processes that incorporate relevant risks, and that they hold sufficient capital to continue operations through adverse economic conditions. In the CCAR, regulators evaluate capital adequacy, internal capital adequacy assessment processes, and capital distribution plans. Once the financial institutions' boards have approved the capital plans, they are submitted to the Federal Reserve for review.

Also, banks with total consolidated assets of more than $250 billion are required to conduct their own annual stress tests (DFA, 2010, Section 165, as amended by the Economic Growth, Regulatory Relief, and Consumer Protection Act of 2018). Regulators set definitions and rules that govern the stress tests, including the scope of application, scenarios, reporting, and disclosure. The company-run stress tests provide forward-looking information that enables regulators and the firms to better understand their risk profile. But the CCAR and company-run stress tests do not consider climate-related risks. In addition to stress testing, the Dodd-Frank Act authorizes to the Board of Governors of the Federal Reserve to "develop and apply such other analytic techniques as are necessary to identify, measure, and monitor risks to the financial stability of the United States" (DFA, 2010, Section 165).

Regulators in some jurisdictions are experimenting with climate risk stress testing. For example, the Bank of England in 2019 announced plans to conduct climate risk stress tests of major U.K. banks and insurers. That year, the Bank of England's Prudential Regulatory Authority (PRA) required insurers to conduct a climate risk stress test based on three scenarios and a prescribed methodology. Also, as part of the Bank's Biennial Exploratory Scenario (BES), scheduled to start in 2021, it will ask major U.K. banks and insurers to estimate the size of climate change risks in three scenarios over a 30-year time horizon and consider how they would adjust their business models under each scenario. To facilitate this analysis, the Bank will provide a set of climate scenarios alongside pathways for macro-financial variables. This will build on the work of the Central Banks and Supervisors Network for Greening the Financial System (NGFS), which has recently developed reference scenarios for central banks and supervisors.

Similarly, the Bank of France, the Australian Prudential Regulation Authority, and the Bank of the Netherlands have completed or are in the process of launching climate risk stress tests for banks and insurers. In March 2020, the European Central Bank (ECB) announced preparations for a macroprudential stress test aimed at understanding how climate risks could propagate across the non-financial economy and the financial system.

Central bank asset purchases. Under existing emergency authorities, the Federal Reserve can purchase financial assets to inject liquidity into stressed markets and to maintain firms' access to finance during adverse conditions. Asset purchase programs were crucial to the central bank's effort to address the financial crisis in 2008 and 2009, and have been revived and expanded to combat the financial impacts of the COVID-19 pandemic. As a result, the Federal Reserve has announced its intention to buy not only the agency mortgage-backed securities and federal government debt it purchases as part of its monetary policy operations to support the macroeconomy, but also municipal bonds and corporate debt in primary and secondary markets, including bonds of companies that fell below investment grade after March 22, 2020. These financial assets will sit on the central bank's balance sheet for an undefined period. If the value of these assets deteriorates, the public ultimately bears the risk. Currently, the Federal Reserve, in conducting asset purchases, does not systematically consider, measure, or disclose transition and physical climate risks.

Commodities and derivatives markets. The Commodity Exchange Act empowers the CFTC to regulate commodities and derivatives markets. That authority includes the regulation of market participants, such as futures commission merchants (FCMs), swap dealers and major swap participants (MSPs), and market infrastructure, including designated clearing organizations (DCOs), designated contract markets (DCMs), and swap execution facilities (SEFs) (CFTC, 2020). Following the financial crisis, the Dodd-Frank Act significantly extended the CFTC's jurisdiction to cover over-the-counter (OTC) derivatives or swaps.

Several CFTC authorities are especially relevant in the context of managing climate risk. The CFTC's regulations require swap dealers to maintain an effective risk management program that covers various risks. DCOs, DCMs and SEFs also must satisfy capital adequacy requirements and maintain a framework for monitoring and managing risk. Also, the CFTC requires swap dealers to "establish, document, maintain and enforce" a system of risk management policies and procedures designed to monitor and manage risks, including market, credit, liquidity, and foreign currency risks, as well as "any other applicable risks" (CFTC Rule 23.600). Other applicable risks presumably could include climate-related risks if they are deemed material. Swap dealers also are required to satisfy all capital and margin requirements established by the CFTC or any prudential regulator (CFTC Rule 23.600(c)(6)).

CFTC Rule 23.600(c)(2) requires swap dealers to make quarterly written reports to their senior managers and governing body, setting forth their market, credit, liquidity, foreign currency, legal, operational, settlement and any other applicable risk exposures, as well as any recommended or completed changes to their risk management program. These quarterly reports must be submitted to the CFTC within five business days of providing them to senior managers. The CFTC also conducts clearinghouse supervisory stress tests. Three have been conducted so far. The tests have included clearinghouse liquidity risks, though the tests have not covered operational risks, including risks from climate-related physical impacts.

Insurance. The U.S. system for regulating insurance markets vests authority with state insurance regulators. Under this system, unless a federal law explicitly preempts states from regulating some aspect of insurance, state insurance regulators' authority is governed by state laws and regulations. Because climate change-related impacts can pose risks to insurance companies as underwriters or investors, insurance regulators could use their authority under state laws and regulations to identify, monitor, and address climate-related physical and transition risks facing individual insurance companies and the insurance sector more broadly. If state insurance regulators need additional authority, states can enact laws granting it.

Insurance regulators can require stress testing to better understand insurers' risk profiles and capacity to absorb losses. For example, California's Insurance Commissioner conducted a climate risk scenario analysis of insurers' investment portfolios—the only state so far to do so (CDI and UC Berkeley CLEE, 2018). Unlike insurance regulators in other countries, including the Bank of England, the Bank of the Netherlands, and the Bank of France, no U.S. state insurance regulator has undertaken climate risk stress tests of insurance companies.

Credit rating agencies. Credit rating agencies provide information that is actively used by investors in the financial marketplace. The U.S. Securities and Exchange Commission (SEC) can prescribe rules requiring rating agencies to submit an annual internal controls report, which must contain, among other things, "an assessment of the effectiveness of the internal control structure" of the agencies (DFA, 2010, Section 932). The control structure governs the implementation of "policies, procedures, and methodologies" for determining credit ratings (DFA, 2010, Section 932).

In recent years, credit rating agencies have started to consider climate-related risks in their ratings. For example, one rating agency cited environmental, social, and governance (ESG) risks as material credit considerations in a third of the more than 7,600 private sector rating actions published in 2019 (Mutua, 2020). Progress has been notable in the incorporation of physical climate risk variables into sovereign and municipal bond ratings, as well as into ratings of some corporate debt.

Disclosure and Investor Protection

Under existing authorities, financial regulators have broad authority to require disclosure of material information to regulators, investors, customers, and counterparties. Chapter 7 provides an additional discussion of disclosure-related authorities.

Banks and nonbank financial companies. Under the Dodd-Frank Act, the Board of Governors of the Federal Reserve can require periodic public disclosures by nonbank financial companies it supervises and by bank holding companies of a certain size "to support market evaluation of the risk profile, capital adequacy, and risk management capabilities" of those companies (DFA, 2010, Section 165). These disclosures are in addition to the disclosures required by the SEC for publicly listed banks and nonbank financial institutions.

Securities issuers. The SEC is charged with protecting investors and maintaining fair, orderly, and efficient capital markets. Firms issuing securities to the public must register with the SEC and disclose information about the company, its management, how the firm intends to use the funds raised through the sale of securities, and material risks to investors. Not only are publicly traded corporations required to register, but so are other securities-market participants, such as stock exchanges, securities brokerages, mutual funds, auditors, and investment advisers.

SEC Regulation S-K provides disclosure requirements for publicly traded companies. Under Regulation S-K, public companies are required to disclose material information—known trends, events, or uncertainties that are "reasonably likely to have a material effect" on the company's financial condition or operating performance—through annual or other public filings (SEC, 1989). In 2010, the SEC issued guidance "to remind companies of their obligations under existing federal securities laws and regulations to consider climate change and its consequences as they prepare disclosure documents to be filed with us and provided to investors" (SEC, 2010). As discussed in more detail in Chapter 7, the guidance has not had a significant impact on actual climate risk disclosures by companies because of its lack of specificity and uneven application (Stevenson, 2019; Gelles, 2016).

Commodities and derivatives markets. Under the Commodity Exchange Act and CFTC regulations, the CFTC can require a range of upstream and downstream risk disclosures, including scenario analyses, in some circumstances. For example, certain market participants are required to make upstream financial disclosures to DCOs, DCMs and SEFs. Under the CFTC's rules, risk disclosures primarily are made downstream, such as from swap dealers and FCMs to their counterparties and customers. In contrast to the broad company disclosures required by the SEC and other regulators, the CFTC-required disclosures are primarily product disclosures. However, they could be interpreted to specifically require addressing climate-related risks to certain commodity contracts.

For example, under the CFTC's business conduct rules, swap dealers must disclose to their counterparties, before entering into a swap, material information concerning it. This must be done in a manner reasonably designed to allow the counterparty to assess, among other things, the material risks of the swap (such as market, credit, liquidity, foreign currency, legal, and operational risk).[3] Before entering into a swap, the swap dealer also must notify the counterparty of its right to request and consult on the design of a scenario analysis. The purpose of the scenario analysis is to allow the counterparty to assess its potential exposure in connection with the swap over a range of assumptions, including severe downside stress that would result in significant losses (CFTC Rule 23.431(b)).

Insurance. State insurance regulators can require insurance companies to disclose a variety of risk-related information, including climate-related risks. Those disclosures can be made public by the regulators (NAIC, 2019; CDI, 2018). For example, since 2011, the National Association of Insurance Commissioners (NAIC) Climate Risk Disclosure Survey has been administered to insurance companies by regulators in California, New York, Washington, Oregon, and Connecticut. The California Department of Insurance (CDI) publishes the survey results on its website. The Climate Risk Carbon Initiative of the California Department of Insurance requires insurers above a certain annual premium threshold to report their investments in thermal coal, oil and gas enterprises, and utilities deriving 50 percent or more of their electricity from fossil fuels. The Department discloses the results on its website. In addition, state laws grant state regulators broad powers of financial examination as well as the authority to request information from insurers through mandatory "data calls."

State insurance regulators do not require insurers to make climate risk disclosures as recommended by the Task Force on Climate-related Financial Disclosures (TCFD). Six state insurance regulators require insurers with premiums in excess of $100 million a year to answer the annual NAIC Climate Risk Disclosure Survey. The survey effectively covers about 1,000 insurers representing 70 percent of U.S direct written premiums. However, the survey is outdated (it was designed in 2009 and not updated since), it does not collect quantitative information, and it falls far short of the disclosures recommended by the TCFD.

Financial Market Utilities

Finally, U.S. regulators have broad authority to oversee the operational and financial resilience of financial market utilities and other critical service providers. For example, the FSOC can designate FMUs or payment, clearing, and settlement activities as systemically important based on, among other things, "the effect that the failure of or a disruption to the financial market utility or payments, clearing, or settlement activity would have on a critical markets, financial institutions, or the broader financial system" (DFA, 2010, Section 804).

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[3] *Note that swap dealers utilize standard disclosures prepared by International Swaps and Derivatives Association (ISDA), including the Physical Commodity Disclosures, which generally address risks regarding underlying physical commodities and markets.*

Once designated an FMU or other financial institution is designated as systemically important, the Board of Governors of the Federal Reserve can prescribe risk management standards governing their operations related to the payment, clearing, and settlement activities. The CFTC and the SEC can do the same for the operations of critical service providers under their jurisdiction. Climate-related impacts are not incorporated into these risk management standards. Financial regulators are studying the potential impacts of cyberattacks aimed at disrupting FMUs (OFR, 2017). Lessons drawn from this exercise may be relevant and useful in the context of climate-related operational risks to FMUs.

Recommendations

Market participants and the regulatory community, in the United States and abroad, are in the early stages of understanding and experimenting with how best to monitor and manage climate risk. Given the considerable complexities and data challenges involved, regulators and market participants should adopt pragmatic approaches that stress continuous monitoring, experimentation, and learning. Regulatory approaches in this area are evolving and should remain open to refinement, especially as the understanding of climate risk continues to advance and new data and tools become available.

At the same time, regulators should establish a clear framework with appropriate milestones. This is what financial regulators are already doing in some jurisdictions and is consistent with recommendations of financial regulatory bodies (Bank of England, 2019; Bank for International Settlements, 2020; NGFS, 2020). As explained above, in general, regulators have sufficient authority to start tackling climate risk immediately. The following recommendations provide, in our view, a good starting point.

Systemic Risk Oversight

Recommendation 4.1: All relevant federal financial regulatory agencies should incorporate climate-related risks into their mandates and develop a strategy for integrating these risks in their work, including into their existing monitoring and oversight functions. Regulators should further develop internal capacity on climate-related risk measurement and management, including through their strategic planning, organizational structure, and additional resourcing.

Recommendation 4.2: The Financial Stability Oversight Council (FSOC), of which the CFTC is a voting member, should undertake the following:

- As part of its mandate to monitor and identify emerging threats to financial stability, incorporate climate-related financial risks into its existing oversight function, including its annual reports and other reporting to Congress;
- Encourage and coordinate, across the Council's member agencies, the sharing of best practices concerning the monitoring and management of climate-related risks, the building of relevant institutional capacity, the integration of climate-related risks into

the risk monitoring function of the agencies and into financial supervision and regulatory frameworks, and the potential for second-order impacts, such as the migration of financial activity from one part of the financial system to another; and

- Task the Office of Financial Research with developing a long-term program of research on climate-related risks to the financial system, paying close to the potential interconnectivity and spillovers of climate-related risks across the financial system; monitoring relevant developments; and developing tools that regulators can use for the monitoring and management of climate-related risks.

Recommendation 4.3: Research arms of federal financial regulators should undertake research on the financial implications of climate-related risks. This research program should cover the potential for and implications of climate-related "sub-systemic" shocks to financial markets and institutions in particular sectors and regions of the United States, including, for example, agricultural and community banks and financial institutions serving low-to-moderate income or marginalized communities. Research should also include the impact of climate risk on financial system assets and liabilities, including by sensitivity of specific sectors to climate change, geographic location, and tenor. In doing so, regulators should identify data gaps and approaches to address these shortcomings. Regulators should develop assessments of the magnitude of the impact of climate on these assets and liabilities, for example through scenario analysis.

Recommendation 4.4: Relevant federal regulators should assess the exposure and implications of climate-related risks for the portfolios and balance sheets of the government-sponsored enterprises (GSEs) and strongly encourage the GSEs to adopt and implement strategies to monitor and manage those risks.

Recommendation 4.5: The Federal Insurance Office, in collaboration with state insurance regulators, should undertake an assessment of the insurance sector's systemic vulnerability to climate-related impacts and report the findings to the FSOC. FIO should also evaluate the adequacy of state insurance regulators' oversight of climate-related risks.

Recommendation 4.6: Federal financial regulators should actively engage their international counterparts to exchange information and draw lessons on emerging good practice regarding the monitoring and management of climate-related financial risks. U.S. regulators should join, as full members, groups convened for this purpose, including the Central Banks and Supervisors Network for Greening the Financial System (NGFS), the Coalition of Finance Ministers for Climate Action, and the Sustainable Insurance Forum (SIF). The United States should also engage actively to ensure that climate risk is on the agenda of Group of Seven (G7) and Group of Twenty (G20) meetings and bodies, including the Financial Stability Board (FSB) and related committees and working groups. The Federal Reserve already participates in the Basel Committee on Banking Supervision's climate task force, and the Securities and Exchange Commission participates in the International Organization of Securities Commissions' (IOSCO) sustainable finance network.

Risk Management

Recommendation 4.7: Financial supervisors should require bank and nonbank financial firms to address climate-related financial risks through their existing risk management frameworks in a way that is appropriately governed by corporate management. That includes embedding climate risk monitoring and management into the firms' governance frameworks, including by means of clearly defined oversight responsibilities in the board of directors.

Recommendation 4.8: Working closely with financial institutions, regulators should undertake—as well as assist financial institutions to undertake on their own—pilot climate risk stress testing as is being undertaken in other jurisdictions and as recommended by the NGFS. This will enable stakeholders to better understand institutions' exposure to climate-related physical and transition risks, as well as to explore climate-related opportunities. The pilot program should include the testing of balance sheets against a common set of scenarios (elaborated on in Chapter 6 and Recommendation 6.6), covering how financial institutions might respond to climate-related risks and opportunities over specified time horizons. This climate risk stress testing pilot program should include institutions such as agricultural, community banks, and non-systemically important regional banks.

Recommendation 4.9: Regulators should closely monitor international experience with climate risk stress testing of banks and insurers and apply relevant lessons to the U.S. context. U.S. regulators should engage in international forums, such as the NGFS, to ensure that climate risk stress testing conducted in the United States is comparable to similar exercises in other jurisdictions and avoid duplicative exercises for institutions with a multi-jurisdictional footprint.

Recommendation 4.10: Financial authorities should consider integrating climate risk into their balance sheet management and asset purchases, particularly relating to corporate and municipal debt.

Recommendation 4.11: The CFTC should:

- Undertake a program of research aimed at understanding how climate-related risks are impacting and could impact markets and market participants under CFTC oversight, including central counterparties, futures commission merchants, and speculative traders and funds; the research program should also cover how the CFTC's capabilities and supervisory role may need to adapt to fulfill its mandate in light of climate change and identify relevant gaps in the CFTC's regulatory and supervisory framework;

- Drawing on the conclusions of the research program above, review the extent to which existing CFTC rules are adequate to monitor and manage climate-related risks. For example, CFTC should review the extent to which rules for non-centrally cleared over-the-counter derivatives (NCD) are appropriate for monitoring and managing climate-related risks. It should also review rules related to capital and margin requirements of

futures commission merchants and swap dealers, as well as initial margin and default fund rules, risk management rules, and capital requirements pertaining to central counterparties;

- Expand its own central counterparty stress testing to cover the operational continuity and organizational resilience of central counterparties, including organizational resilience of operations, contingency planning, and engineering resilience for facilities exposed to climate-related physical risks. Where central counterparties and market infrastructure are not within the CFTC's direct supervisory remit, the supervision of physical risks should be addressed by the relevant FSOC member in a consistent fashion; and

- As better understanding emerges of the risk-transmission pathways and of where the material climate risks lie, consider expanding the CFTC's risk management rules and related quarterly risk exposure reports to cover material climate-related risks.

Recommendation 4.12: State insurance regulators and insurance regulators' supervisory colleges, which are convened by regulators where an insurer or its subsidiaries or affiliates operate in multiple jurisdictions, should:

- Require insurers to assess how their underwriting activity and investment portfolios may be impacted by climate-related risks and, based on that assessment, require them to address and disclose these risks; and

- To facilitate the risk assessment mentioned in the point above, insurance regulators should conduct, or require insurance companies to conduct, climate risk stress tests and scenario analyses to evaluate potential financial exposure to both the physical and transition impacts of climate change; state insurance regulators should provide the scenarios, assumptions, and parameters for the stress testing exercise.

Recommendation 4.13: Regulators should require insurers to integrate consideration of climate risks into insurers' Enterprise Risk Management (ERM) and Own Risk Solvency Assessments (ORSA) processes.

Recommendation 4.14: Regulators should require credit rating agencies to disclose the extent to which their ratings take into account climate risk, including for issuers of corporate, municipal, and sovereign debt. This should include a disclosure of applicable methodologies for those credit rating products that consider climate risk.

Disclosure

See Chapter 7 for recommendations on disclosure.

Financial Market Utilities

Recommendation 4.15: Federal regulators should ensure that risk management standards governing the operations related to the payment, clearing, and settlement activities of FMUs incorporate measures to monitor and manage physical climate risks. The CFTC, in its capacity as an FSOC member, should recommend that the Council oversee and coordinate this process as it pertains to FMUs designated as systemically important.

Recommendation 4.16: The CFTC should review the extent to which financial market infrastructure—including but not limited to systemically important FMUs for which it is the primary regulator—is resilient against losses that could arise through the physical impacts of climate change.

Chapter 5

A Closer Look at Climate Risk Management and Data

This chapter examines climate-related risk management by financial institutions. It reviews the components of physical and transition risk, building on the description of ongoing and potential climate impacts in Chapter 2. It then explores several important questions: How can more robust climate risk data and better analytics be developed, and how can financial institutions continue to build their capacity to utilize climate analytics to inform business decisions? What kind of analysis should be undertaken to complement existing risk management? How can climate-related risk analysis support and strengthen risk management across different parts of the financial system?

As referenced in Chapters 2 and 3, climate change has broad implications for macroeconomic performance, including inflation, interest rates, balance of payments, productivity, wealth, and gross domestic product (GDP) growth. Physical and transition risks could profoundly impact, among other things, valuation, credit risk analysis, and asset-liability matching. Climate change also has specific locational considerations and impacts on individual physical assets and the firms that own those assets. It can also affect complex supply chains, as well as public and private infrastructure that supports the economy. Understanding and developing tools to analyze and monitor qualitative uncertainties and quantitative risks, including location-specific risks, requires a variety of datasets, methodologies, and measurement technologies. Effectively managing climate risk requires understanding the vulnerability and resilience of economic actors and markets to climate risks because transition and physical risks from climate change do not uniformly impact companies, countries, sectors, or geographies.

While there is no one-size-fits-all methodology, tool, or scenario, many approaches may be appropriate for different cases. Integrated environmental and economic datasets and methods are relatively new and evolving so any climate risk management approach should be flexible and allow for ongoing learning and the incorporation of best available science and technology. Climate risk management should recognize that confidence intervals and the accommodation of uncertainty may vary considerably between scientific and financial stakeholders.

Required levels of confidence, spatial and temporal scales, and the range of potential climate-attributed shocks and stresses associated with physical and transition risks will govern the most suitable approaches for any given financial institution. In each instance, the inherent uncertainties, non-linearities and feedback sensitivities associated with climate change need to be considered; they increase the further into the future one attempts to look. Scenario analysis, covered in Chapter 6, seeks to inform and identify parameters and indicators to better manage deep uncertainties. This chapter focuses on how climate risk analysis can be applied to support and strengthen climate risk management, and the barriers to achieving this goal.

The Demand for Climate Risk Management and Data

To undertake climate risk management, firms need reliable, consistent, and comparable data and methodologies. Climate risk management helps firms adapt to changes in markets arising from physical and transition risks and it helps them build resilience so they can continue to deliver products and services in the face of those risks. Drawn from several decades of international consensus building through the Intergovernmental Panel on Climate Change (IPCC) and the U.S. National Climate Assessments (NCA), these concepts have been widely applied and internalized into the governance and management of firms (Winston, 2014; Linnenluecke, 2017; McKnight and Linnenluecke, 2019). The following summarizes the key concepts framing current climate risk data and management practices. These concepts are consistent with the official definitions promulgated by the interagency U.S. Global Change Research Program (USGCRP), as ratified by the National Academies of Sciences, Engineering, and Medicine (NASEM).

Adaptation and Resilience

Firms' two-pronged goal should be to adapt to climate change by addressing physical climate impacts and transitioning to a net-zero economy. *Adaptation* is defined as, "[an] [a]djustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects" (USGCRP, 2020). In this sense, adaptation is not only about managing risk, it is also about taking advantage of opportunities that may arise in broader transformations of markets, including transformations shaping a more sustainable and equitable economy. For firms, the goal is to develop a robust *adaptive capacity*, which can be defined as, "[t]he potential of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, take advantage of opportunities, and cope with the consequences." (USGCRP). (A system could include, for example, a firm or a market.) Because of the many uncertainties of climate change, firms should strategically build a capacity to adapt to a variety of knowns and unknowns. To build the adaptive capacity of a firm, its executives may institute *adaptive management* processes that involve "iteratively planning, implementing, assessing and modifying strategies for managing resources in the face of uncertainty and change" (Keenan, 2018, p. 146). In 2019,

the International Organization of Standardization (ISO) published the first adaptation standard (ISO 1490:2019) aimed at supporting firms' adaptive management (ISO, 2019).

While adaptation and adaptive capacity frame the broader ambitions of firms and markets, in the near-term they must also build a capacity for *resilience*, which is defined as, "[a] capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment." (USGCRP, 2020). The resilience of a market or a financial system can be understood as its capacity to withstand various shocks and stresses and still maintain critical levels of performance. At the firm level, *organizational resilience* is the capacity to identify, diagnose, and manage external shocks and stresses to continue operations and regular business activities (Sahebjamnia, et al., 2015). Firms' organizational resilience activities may include everything from business continuity planning to contingent contracting for alternative supply chains. Other types of resilience, including *community resilience* and *ecological resilience*, are also central to supporting impact driven decision-making.

Defining Climate Risk Management and Data

Firms should focus their risk management and long-term governance on building their capacity to adapt to new markets, products and services, while at the same time developing the organizational resilience to be able to actually deliver those products and services in the face of immediate shocks and stress, including both climatic and non-climatic events. Beyond preparing for physical risks, firms should adapt their businesses to facilitate and participate in a transition to a net-zero economy. Managing transition risks includes taking advantage of opportunities associated with new forms of sustainable production and consumption.

Climate risk is categorized as either transition or physical risk. But as Chapter 2 explains, sometimes these categories are not easily bifurcated. In other cases, certain types of physical risks are widely understood as known natural, technological, and human-caused hazards (FEMA, 2009). Both physical and transition risks, because they are novel, represent a challenge to the analytical parameters of conventional risk management, which often focus on specific plausible, but extreme events that have some basis in prior experience. Because risk is technically a probabilistic function of exposure, sensitivity and consequence, the novelty of climate change means that there is greater uncertainty and ignorance about the range of possible outcomes (USGCRP, 2020). Climate risk should properly be conceptualized as a combination of physical and transition risks—and uncertainties. To build their adaptive capacity and organizational resilience, businesses must develop near real-time intelligence that allows them to better understand a range of plausible events and scenarios. U.S. financial regulators, who are the stewards of the stability of the financial system, also must build these capacities for climate risk management. Together, the processes of adaptation and resilience within climate risk management define the demand for climate risk data.

Climate risk data is highly complex and relies on translating scientific and economic models into financial transmission pathways and then into decision-useful financial variables and metrics. In developing this data, time horizons should be considered, given that financial exposure can be somewhere between short-term, relative to certain climate risks, and long-term, for the duration of a durable asset class. Data should allow for both bottom-up and top-down analysis at the appropriate level of detail for the use case (the specific situation in which a product or service will be used). Ideally, available data would support a wide variety of estimates and projections, covering appropriate time horizons with levels of detail, geographical coverage, and confidence relevant to the particular use case. In this ideal situation, these models would produce decision-useful data that are comprehensive, consistent, and comparable and that would inform assessments of the underlying risk, uncertainty, and vulnerability of firms, counterparties, assets, and markets.

Vulnerability is a composite measure of exposure, sensitivity and, in this case, the adaptive capacity of a firm to manage the climate risks of a particular asset. *Exposure* reflects the presence of financial assets coinciding with climate impacts—namely acute extreme events or recognizable patterns of stress. Exposure is the prerequisite to the transmission of climate risks to financially relevant metrics. *Sensitivity* reflects a measure of the responsiveness of exposed assets to any given shock or stress. For instance, an asset with high exposure and low sensitivity may not be too adversely impacted. Table 3.1 provides examples of financial assets exposed to climate risks. While an ecosystem of climate data is emerging, much of the advances in measuring and evaluating asset exposure have not been accompanied by corresponding advances in evaluating the sensitivity of exposed assets or the adaptive capacity of firms to manage sensitivity and exposure. Physical risk data and projections need to be overlaid with exposure data at the asset level. Some financial institutions may have asset-level data to overlay with physical risk data, for example, a bank providing project finance loans. However, most finance use cases will not have direct access to asset-level data for counterparty analysis, let alone analysis of multiple counterparties in a portfolio (such as a listed equities portfolio). Understanding the vulnerability of exposed assets and counterparties to climate risk requires a wide variety of qualitative and quantitative metrics, and detailed data is largely unavailable across most use cases.

Expanding Climate Risk Data

The increasing adoption of climate risk management practices should incentivize the development of more robust climate risk data. However, while physical risk data is more widely available than transition risk data, both are generally insufficient, and several barriers impede the development of robust decision-useful data. Effective risk management in general, including scenario analysis as described in Chapter 6, relies on the analysis of physical and transition risk data. The two primary barriers to expanding the quality and availability of climate risk data are (i) availability and (ii) standardized definitions.

Availability

Climate data and supporting measurement technologies and analytical methodologies are rapidly advancing in what is now understood as an emergent climate services sector. However, the quality and interoperability of these services is at a relative early stage. Significant gaps in sectors and across asset classes are impeding not only climate risk management, but also aspects of operations and investment analysis that depend on data-informed processes.

The availability of climate data depends on a variety of public, private and civic sector sources. Historically, climate data was largely environmental and weather data produced by government agencies. Today, climate data serves to help market actors understand climate-related vulnerability in both qualitative and quantitative terms. It may reside: (i) in company disclosures to financial markets, regulators, and government agencies (in multiple jurisdictions and in different languages); (ii) in voluntary disclosures; (iii) in existing proprietary and non-proprietary databases; (iv) in public and private research institutions; and, (v) in academic research. However, the challenge is finding the relevant sources if they exist, and then validating, cleaning, and standardizing the data in an accessible form or format. Chapter 7 addresses corporate disclosure of climate risk information.

Ideally, relevant data would be available and structured to facilitate extraction for financial or sustainability reporting. However, many companies currently either do not report, or report only limited information. Further, calculation methodologies and reporting formats are not standardized. As a result, information is not comparable, causing measurement divergences. It is extremely difficult for individual institutions to secure all the data necessary for detailed datasets. Innovative technologies, such as "data mining" and remote sensing, could open new avenues for generating, at low cost, detailed climate risk data relating to both listed and non-listed companies.

Several organizations offer solutions to address these data and methodological challenges. Different providers collect carbon emissions data, largely based on company disclosures, while other providers use proprietary methods to estimate emissions data. For physical risk, several providers have developed models to assess the frequency and severity of physical perils based on future emissions pathways, predominantly IPCC scenarios. Coverage, including geography and level of detail, varies across these providers. This data and related services can be expensive, and licensing may restrict or otherwise impede integration into broader climate risk tools. It can often be too expensive for smaller firms, which instead rely on public data from government sources or academic institutions, which may specialize within local geographies. However, the value of this data is a key driver of related financial and risk management innovation. U.S. financial regulators or industry bodies may be able to develop common data platforms and technical standards to enable the flow of data in accessible formats. External organizations and public open access platforms also are seeking to address costs that may be incurred by parties that use and disclose climate risk data, including from internal specialists, technology systems, and consulting services.

At the heart of efforts to make climate-related data more accessible are two objectives, which can at times be in tension with each other: the expansion of public open access to climate data on one hand, and the development of proprietary intellectual property related to climate data and services, on the other. There is great demand for public open access to climate data, including primary data based on public and civil sector measurement infrastructure. The American Meteorological Society has taken steps to support principles that guide further development of open access environmental and climate data (AMS, 2019). These efforts are important for ensuring that a robust process can inform decision-making in both the public and private sectors. Market participants who want to compare publicly available disclosure information and sustainability-benchmarked financial products also would benefit from open access data. Open access data is important for consumer transparency, scientific integrity and market development.

At the same time, proprietary intellectual property that will drive innovation in technologies and climate-related data and services also is needed. These technologies and services are necessary to facilitate the data underlying climate risk management and disclosure. In recent years, increased investment in climate data technologies has been a positive sign for the commercialization of underlying intellectual property and the recognition in the private sector of its value. The challenge ahead will be to balance both the public and private objectives in the interests of both transparency and innovation. Appendix Table 1 includes a sample of public and civil society efforts to increase the availability of climate risk data. There are a wide range of private sector activities, not covered in the Appendix.

Standardized Definitions

A common set of definitions for climate risk data—including modeling and calculation methodologies—is important for developing consistent, comparable, and reliable data. For data to be decision useful, it is necessary to know which climate-related variables materially impact the performance of markets, countries, sectors, asset classes, companies, projects, and securities, and how these variables interact. While these interactions often defy analysis, the ambition to better understand them remains. These fundamental research questions inform what data should be disclosed, including unit of measurement, frequency, and format.

Common definitions for climate risk data include reporting formats and calculation methodologies that can help mitigate limitations. However, lack of standards, and differences among standards, can create barriers to climate risk management. Voluntary disclosure frameworks, as described in Table 7.1, have helped significantly, but in the aggregate these frameworks identify more than 165 potentially "material" metrics, an overwhelmingly large number for many financial institutions. In some cases, different units of measure are stipulated for similar metrics across frameworks. Organizations are actively working to address some of these standards issues, but further work is needed.

An example of the challenges around climate risk data is the wide variation in available ESG (environmental, social, and governance) and climate scores. Massachusetts Institute of Technology research has found that ESG scores from the main five ESG data providers are uncorrelated for any given company (Berg, et al., 2019). Many practitioners are uncertain about which factors are best suited for particular use cases, a problem compounded by lack of transparency into underlying data and methodologies.

There is little international coordination on data and methodology standards, and existing efforts may conflict with the direction the United States may take. In 2018, The European Commission (EC) established a technical expert group (TEG) on sustainable finance to develop a European Union (EU) classification system—the EU taxonomy—to determine whether an economic activity is environmentally sustainable, as well as other related definitional standards for climate-related data and financial products. A goal of the EU taxonomy is addressing data inconsistencies by providing a single, methodologically transparent, and rigorous standard to judge the environmental attributes of financial products as sustainable and non-sustainable. However, explicitly setting thresholds poses challenges, particularly given the diversity of the U.S. economy and the context of the U.S. regulatory structure.

In general, taxonomies, standardized definitions and classification systems can help enable transparency and comparability. Consistency and reliability in climate risk data would then allow financial institutions to compare assets and companies, among other objectives. This could unleash competitive dynamics around managing climate risk that would increase resilience, including via "green" activities.

The United States should develop guidance supporting the comparison and reliability of climate risk data and financial products and services. The guidance should account for the nuances of the U.S. economy and regulatory system and build on the lessons learned in the EU and other jurisdictions, including China and Brazil. Development of this guidance could occur through the establishment a Standards Developing Organization (SDO) composed of public and private sector members. Given the potential downsides of standardization, the SDO should ensure it does not overly raise barriers to entry or restrict innovation. The SDO can work with international counterparts and the private sector to memorialize emerging best practices that advance climate risk management and the development of sustainable financial products and services. The NASEM can provide a foundation for the scope of SDO activities by convening public, private, civic, and international stakeholders to promulgate a consensus study report to Congress. Currently, market-based opinion and assurance bodies are serving this function for financial products, and these services are important for continued market development. For standards and guidance to be optimally effective, there will ultimately need to be multilateral global coordination in the development, maintenance, and benchmarking of relevant indicators, reinforced by robust disclosure practices.

Scope 3 Emissions and Transition Risk

The Greenhouse Gas Protocol is a widely used global standardized framework for categorizing emissions as Scope 1, 2 or 3. Scope 1 emissions are direct emissions from owned or controlled sources, and Scope 2 emissions are indirect emissions from purchased energy (electricity, steam, heat and cooling) generated by external entities. Scope 3 emissions encompass all other indirect emissions across the value chain, including both upstream and downstream. Scope 1 and 2 data is much more available than Scope 3 data.

Scope 3 emissions are a proxy for and an important input to transition risk, particularly for bottom-up company-specific analysis, as they reflect transition exposure. For automakers, Scope 1 and 2 emissions include vehicle manufacturing, while Scope 3 emissions include the upstream supply chain as well as the downstream gasoline, diesel, or electricity that customers use to operate vehicles. The Scope 1 and 2 emissions from operating a building are dwarfed by the Scope 3 emissions from steel, cement, and other materials used during construction. However, Scope 3 emissions represent only a portion of transition risk, and complementary data is required to make Scope 3 emissions fully decision useful. Among other factors, emissions intensity, demand and supply elasticity, and the associated pass-through of production prices to consumers impact vulnerability in the short-term, while transition plans, evolving consumer preferences and technology innovation impact vulnerability in the longer-term. Effective risk management requires focus on the full spectrum of transition risk. For example, to assess oil and gas company transition risk from carbon pricing, key inputs include capital structure, marginal cost of production, emissions intensity of products, and duration of reserves.

Financed emissions are a special category of Scope 3 emissions, reflecting the indirect emissions underlying financial portfolios, products and services. Financed emissions can help highlight the point-in-time carbon exposure of a financial institution, portfolio or product, but need to be complemented with a range of other data (for example, use of proceeds from a financing and companies' emissions trajectories and financial capabilities) and specifics of the underlying portfolio or financial product (such as asset class, duration, diversification, geographic exposure, hedging, and risk mitigation) to be decision useful for transition risk management. Businesses are increasingly committing to net-zero emissions, and increased sustainable investments by an institution could cause its financed emissions to decline.

In addition, design issues specific to financed emissions raise challenges, particularly around allocating emissions to the wide range of financial activities. Financed emissions from owning 1 percent of a company might include 1 percent of that company's emissions; a portfolio can rapidly double count if aggregate financed emissions include each underlying company's own Scope 3 upstream and downstream emissions. The calculation becomes significantly more complex with other activities, such as when a financial institution serves as a counterparty or is one of multiple underwriters of a financing.

There is no agreed standard for financed emissions and little consistency or comparability to date, but a wide range of methodologies are being developed. Existing estimation methods present significant challenges and regulators should encourage the market to develop a more consistent way of measuring and reporting Scope 3 emissions across sectors where they are material and relevant.

Climate Risk Analysis

Effective traditional risk management includes identifying risks, defining risk categories, setting the company's risk appetite, quantifying the risks, and then monitoring and mitigating risks to stay within the determined risk appetite. Effective climate risk management needs to be integrated into this existing risk management process, including defining the risk categories impacted by climate risk—credit, market, strategic, insurance, liability, underwriting, operational, and reputational.

With reliable, consistent, and comparable data, analytical tools and methodologies can be developed to identify, assess, monitor, and manage climate risk within financial markets, as indicated by relevant risks, uncertainties, and vulnerabilities. Then firms may be able to develop an ongoing management capacity to adapt to physical and transition risks and to develop the resilience of their organizations, supply chains, and markets. Many financial institutions are already starting to do this, but climate risk analysis requires a different set of evolving methodologies, tools, and data sets to account for the many assumptions, inherent uncertainties, and long time horizons. These factors will be applied differently depending on roles, asset classes, relevant available climate risk data, and investment horizons. As an illustration, the following are steps that a financial institution can take in applying climate risk analysis.

Risk Identification

The first step in identifying potential vulnerabilities to different types of climate risks is a qualitative or quantitative exercise that categorizes climate risks and then applies the categories to the relevant asset classes, sectors, and geographies. This can be done, for example, through a heat-mapping exercise. For transition risk, the identification exercise may use exposure and vulnerability data on the carbon intensities of different sectors and assumptions about a firm's elasticity and ability to pass-through costs. For physical risk, the exercise may use forward-looking climate data to discern the exposure and vulnerabilities of different sectors to specific climate impacts based on their geographic location, as well as their ability to improve resilience with hardening measures. Mapping out risks should include the transmission mechanisms of climate risk into financial products and services. For example, banks that have more concentrated long-dated loans are likely to face greater credit risk exposure through their lending than asset managers, which have greater market risk exposure.

Risk Assessment and Measurement

Next, financial institutions need to quantify their risks. Climate risk is particularly difficult to assess and measure since it is highly uncertain, non-linear and can affect different types of assets, companies, sectors, and geographies differently. Financial institutions may use various approaches, including top-down or bottom-up, based on the type of risk, the structure of their business, and the balance between the efficiency of the analysis and its effectiveness

in informing risk management decisions. For example, to assess its liquidity position, a bank may consider a top-down climate stress test, applying a set of asset-based shocks to its tradable assets. Such a top-down approach may be relevant for a bank that has a diverse global portfolio of credit counterparties and a loan book that is more short-term and marked-to-market. Bottom-up approaches often require asset-level data, which is often limited.

A range of analytical methods may be necessary to manage credit risks and distinguish relative vulnerabilities within a portfolio. Examples could include portfolio review by sector or specific analysis of more material exposures, such as bottom-up analysis at the company-level. This may require enhanced due diligence of companies to gather the relevant climate risk data such as Scope 1, 2 and 3 emissions exposure, elasticity studies to understand vulnerability to price adjustments, and organizational resilience efforts, including insurance and business model transition plans. Physical risk assessment for material exposures in particular requires asset-level analysis since it is location specific. However, some transition risk assessments may also require geographic data (for example, for a power company, the electricity generation mix of coal, gas, renewables, and nuclear and whether it operates in jurisdictions with current or future carbon regulations). Resilience and the application of risk mitigation measures are critically important and may be evaluated by a firm's (i) utilization of risk transfer mechanisms; (ii) ability to pass through costs; and, (iii) financial wherewithal to manage risk, among other structural mitigants. While financial institutions may have different levels of capacity today, all should work to enhance their assessment protocols and frameworks.

Scenario Analysis

As explored more broadly in Chapter 6, scenario analysis can help incorporate uncertainty into decision-making and is increasingly being used to analyze climate risk. Rather than trying to predict the future precisely, which is inherently unrealistic, scenario analysis attempts to put contours around the range of possible outcomes—from best case to extreme but plausible—by testing scenarios that are the most relevant to business planning and risk management. In doing so it can elucidate the risk of assets and portfolios in inherently hard to predict events. Scenario analysis can inform existing risk management processes, such as counterparty due diligence, concentration monitoring, and industry limit settings, and allow adjustment over time.

Risk Monitoring and Management

Finally, as financial institutions conduct analyses to quantify climate risks and understand risk concentrations and material exposures, they should consider how to effectively size their risk appetite and monitor and manage their climate risk to stay within their risk appetite. For example, metrics such as climate-related value at risk[4] or exposure to high carbon intensity

[4] *Value at risk (VaR) quantifies the size of loss on a portfolio of assets over a given time horizon, at given probability. Estimates of VaR from climate change can be seen as a measure of the potential for asset-price corrections due to climate change (Dietz, et al., 2016).*

sectors could be monitored and managed against established industry limits defined by risk appetite. Monitoring would not only enable institutions to assess changes to climate risk exposure and sensitivity over time, but also to identify appropriate adjustments to mitigate the risk. Depending on the nature of their business, financial institutions could shift the allocation of capital in their portfolio from higher climate risk companies to lower climate risk companies, adjust their underwriting and investing exposures to different sectors or geographies, adjust the tenor or other structural aspects of their loans, or reduce insurance underwriting exposure to higher climate risk companies. Financial institutions also could manage climate risk by increasing their sustainable investments (as described in Chapter 8) and by encouraging companies to improve resilience through climate mitigation and adaptation activities.

Building the Necessary Capacity and Skills

A key step in establishing and executing a climate risk framework, including incorporating any requirements by financial regulators as described in Chapter 4, is developing knowledge of the topic and a process for accountability. The assessment of climate risk requires novel capabilities for complex forecasting and data interpretation. Clearly defined governance structures, including at the senior management and board level as well as within existing risk owners, will help guide capacity building.

Firms currently are not investing sufficiently in employees with the analytical skills and experience necessary to understand the suitability of different datasets and methodologies for different use cases. Education and awareness training sessions at various levels of an organization can help, along with a growing number of external resources. For example, a significant body of research has been published, and industry groups and regulators have convened to pilot tools and share best practices. Climate risk management will improve—and regulators' expectations for it will grow—as companies embrace lessons learned from the ongoing development of effective datasets, analysis, and best practices. Overall, sufficient investments in human capital and market intelligence are critical for adaptive capacity and organizational resilience.

Approaches to Climate Risk Analysis Across the Financial System

The financial system comprises a wide variety of financial institutions that play a range of roles. Most institutions will—at some point—likely need to undertake climate risk analysis. However, the specific methods of climate-related risk analysis, as well as its urgency, will vary widely. The following section illustrates how key participants in the financial system could accrue value from climate risk management, depending on the nature of their particular business. Chapter 8 further discusses climate risk management through sustainable investment.

Fiduciary Duty

A wide variety of financial institutions owe various types of fiduciary duties to their beneficiaries and clients. The extent to which fiduciary duties allow or require the consideration of climate risk and other financial ESG factors is an evolving debate in American law (Gary, 2019; Schanzenbach and Sitkoff, 2020). In general, fiduciaries need to consider material risks in supporting the financial goals of their beneficiaries or clients. The duty of loyalty requires the adviser or asset owner to act in its clients' or beneficiaries' best interests, while the duty of care requires the fiduciary to maintain a reasonable standard of care when acting for its client or beneficiary. In many cases, fiduciary duty incorporates an investor's consideration of material risks and the appropriate integration of those risks in investment strategies to support beneficiaries' or clients' financial goals.

Fiduciary duty requires the assessment of material risks and the management of these risks on behalf of stakeholders in keeping with their stated long-term goals, and climate risk is increasingly being recognized as one such risk. As fiduciaries, many asset owners have a responsibility to manage assets on behalf of others and in many cases also match the timing of liabilities (such as, beneficiary payouts) with returns from investments (for example, asset liability management, (ALM)) and ensure that investments are managed for future generations. Climate risk is therefore a key consideration for long-term asset owners who are looking to meet ALM and intergenerational goals. Asset owners with a given mission, including the long-term support of an institution or beneficiary population, should consider the benefits climate-related investments could bring to their financial and mission-given goals. A fiduciary adviser or asset manager owes each of its clients a duty of loyalty and a duty of care and must act consistent with these obligations. As with the beneficiaries of asset owners, the clients of asset managers may have different risk appetites, time horizons and financial objectives. Fiduciary duty also applies to other aspects of the financial system, such as the duty of corporate managers to their shareholders.

Asset Owners

Asset owners, whether they are individual investors or large institutional investors such as pension funds, take risks they deem appropriate to meet their individual or institutional goals. In most cases, and for pension funds in particular, their investment goals are generally focused on maximizing long-term return while minimizing risk. Climate risk impacts are likely to be material at these time horizons. Climate risk management can influence asset owner decisions and activities in many ways.

The impact of climate risk on asset values in different sectors, geographies, and asset classes can inform decisions about strategic asset allocations. Over a longer horizon (10-plus years), a significant portion of returns and risk are attributable to strategic asset allocation, in other words, the relative weighting of investments across different asset classes or different regions. An asset owner with a longer time horizon will want to factor in climate-related

risk when determining, for example, which regions or asset classes to focus on and which to avoid when deploying capital. Subject to normal financial considerations such as asset values, the asset owner might reduce capital allocations to more carbon intense sectors and to countries that are more vulnerable to climate change and increase allocations to transition-resilient asset classes such as clean energy. Asset allocation decisions can act as a hedge to climate risk. For example, allocations to climate-resilient asset classes can be added to hedge against unavoidable climate risk in other asset classes. In addition, for asset owners who invest based on market benchmarks, allocation considerations will need to consider the underlying benchmark.

In screening and constructing their portfolios, asset owners can invest through external asset managers or make direct investments. When investing through external managers, they can at times co-invest alongside these managers. For direct investments and co-investments, asset owners make investment decisions within chosen asset classes such as corporate equity, debt, or infrastructure and project level investments. Climate risk analysis can be incorporated directly into due diligence and screening of investments and can inform investment decisions, including whether to go long or short on, or overweight or underweight, particular opportunities. An investor who forecasts the manifestation of a transition risk, such as imminent climate policy action, may want to create a portfolio that underweights, excludes, or goes short on companies with significant transition risk. Asset owners also can incorporate climate risk analyses in screening and selecting external asset managers—for example, looking at whether a manager's processes appropriately account for and manage "non-traditional" risks, including climate risk, and whether a manager's strategies reflect strong investment processes and fall within risk tolerance guidelines. Asset owners may decide to use thematic asset managers such as those that have a clean energy or sustainable transport focus.

Through portfolio management and stewardship, asset owners monitor and engage with managers and companies to ensure performance over the lifetime of their investments. Knowledge of emerging climate risks, such as increased regional vulnerabilities to wildfires or impacts on assets or company value due to transition risks, can motivate asset owners to encourage asset managers or company managers to enhance their management of climate-related risks—for example, by encouraging resiliency planning and accelerating net-zero transition plans. Through this engagement, asset owners use their influence to drive changes that align with their investment objectives, including objectives for climate risk.

Asset Managers

Asset managers work on behalf of asset owners to meet return objectives while minimizing risk. Asset managers are an extremely varied group, and therefore appropriate approaches to risk management may vary among types of firms, though firms' approaches also have much in common. Like asset owners, asset managers want to understand potential exposure and sensitivity to all types of risk, including climate risk. This is true for individual investment

decisions, portfolio construction, portfolio management and stewardship, and—in the case of certain asset managers that, for example, perform outsourced chief investment officer functions—strategic asset allocation. Asset managers generally have a fiduciary duty to the asset owners whose funds they are managing.

Asset managers generally focus first on meeting investment goals, and second on increasing assets under management. As described above, climate risk analysis is relevant for meeting investment goals through investment screening, portfolio construction, portfolio management and stewardship. In addition, asset managers attract new customers by demonstrating a strong track-record and by aligning with the goals of asset owners. Asset managers that manage climate risk have the potential to generate better risk-adjusted returns than asset managers who do not. In addition, asset managers whose investment approaches align with asset owners' fiduciary and mission goals can benefit from increased interest and assets under management.

To enhance a variety of investment approaches that align with asset owners' goals, asset managers can use climate risk analysis. Asset managers can develop portfolios to meet the growing interest in investing in companies that are actively decarbonizing the economy and avoid investing in companies that are carbon intensive. Asset managers can actively encourage companies to meet their investment goals, including by reducing their climate impact. Climate risk analysis can also be used to create climate-friendly passive investment products, which provide a low-cost way for asset managers to meet client investment objectives.

Commercial and Investment Banks

Banks have wide-ranging risk management frameworks for a variety of risks. Bank risk management frameworks are highly regulated, and Chapter 4 includes recommendations to address climate risk in existing risk management frameworks in a way that is consistent with banks' board-approved risk appetites. Within this risk appetite, banks provide a variety of financial services, each with its own potential use cases for climate risk analysis. These include lending, underwriting, asset management, direct investing, and liquidity and risk management.

In managing climate risk, banks are responding not only to the potential for increased climate risk from vulnerable assets, asset classes and sectors, but also to the wide range of opportunities from financial services and products that integrate physical and transition resilience. Banks are increasingly directing capital to the transition to a net-zero economy and communicating the positive impact of their activities, as are asset owners, asset managers and other types of financial institutions. Climate risk analysis can support the identification of opportunities to direct capital to sustainable investments and provide transparency about these efforts, as discussed in Chapter 8.

As lenders, banks need to understand the risks associated with their loans, including climate risk. For instance, a bank would be wary of lending to projects that faced significant physical risk as well as to companies that faced transition risk that was significant enough to potentially impair their ability to repay. Climate-related risk analysis is important both to individual lending decisions and to loan portfolios. For instance, how would a rapid transition away from fossil fuels change the probability of default of oil and gas borrowers? Scenario analyses and stress tests may increasingly factor into this type of consideration.

Investment banks underwrite securities, facilitating investors' purchase of equity or debt issued by corporations and governments. Securities underwriting depends on investor interest and sentiment, and integrating climate risk may reduce or increase demand for securities on a company and sectoral level. In addition, underwriters can be legally liable regarding appropriate disclosures in selling securities, and often use independent counsel to judge disclosures. Chapter 7 examines adequate disclosure of material climate risk.

Banks can have asset management divisions, with roles and climate risk use cases like those of asset managers. In addition, in certain cases, banks can invest directly, like asset owners. Banks also provide liquidity and risk management products by engaging in a wide variety of transactions with a wide variety of counterparties. As with other financial services, understanding the risk of doing business with these counterparties requires a holistic view of the risk that counterparties will default. Climate risk may be severe enough to jeopardize the counterparty's ability to meet its obligations. Chapter 8 discusses developments in reducing exposure to climate risk within existing derivative instruments and providing new derivative products to hedge against climate risks.

Insurers

Climate-related risks have the potential to affect the performance of insurance companies' core lines of business and, perhaps, the viability of the companies themselves. Climate risk analysis should play a key role in the companies' risk management processes. For instance, insurance companies should consider climate-related physical risk when determining whether to insure consumer and corporate assets, such as homes and offices. To understand their own exposure and vulnerability to climate risk, they also should understand the aggregate risk in their portfolio of policies. Insurance companies should consider climate risk, including applicable measures of resilience, when determining which types of policies, which sectors, and which regions they want to focus on. Finally, insurers are also significant asset owners and therefore should incorporate climate risk analysis into their investment decisions.

Recommendations

Recommendation 5.1: Financial regulators, in coordination with the private sector, should support the availability of consistent, comparable, and reliable climate risk data and analysis to advance the effective measurement and management of climate risk.

- Regulators and financial institutions should support the range of platforms for climate data and analysis, including improving public access to governmental data and expertise that can enable climate risk management. They should also support new and existing open source platforms, as well as proprietary efforts to develop new climate risk datasets and tools that leverage innovative technologies.

Recommendation 5.2: Financial regulators, in coordination with the private sector, should support the development of U.S.-appropriate standardized and consistent classification systems or taxonomies for physical and transition risks, exposure, sensitivity, vulnerability, adaptation, and resilience, spanning asset classes and sectors, in order to define core terms supporting the comparison of climate risk data and associated financial products and services.

- To develop this guidance, the United States should study the establishment of a Standards Developing Organization (SDO) composed of public and private sector members.

- Recognizing that this guidance will be specific to the United States, this effort should include international engagement in order to ensure coordination across global definitions to the extent practicable.

Recommendation 5.3: Financial regulators should proactively encourage capacity building for climate risk management. This should be consistent with the education and training practices supported by agencies in implementing the Sarbanes-Oxley Act of 2002. It should align with and aid in meeting regulator expectations around embedding climate risk in governance frameworks.

Chapter 6

A Closer Look at Climate Scenarios

This chapter takes a closer look at the importance of climate scenarios in climate risk management. Scenario planning, also known as scenario analysis, is a systematic process for making strategic decisions in the face of uncertainty. It has a long history of use in military, political, and corporate planning. Climate scenarios, as advocated by the Task Force on Climate-related Financial Disclosures (TCFD) and others, are used by researchers, policymakers, and, increasingly, corporations to analyze potential climate-related futures, including the economic, social, and environmental implications of achieving different temperature and emissions goals.

Scenarios illustrate the complex connections and dependencies across technologies, policies, geographies, societal behaviors, and economic outcomes as the world strives toward a net-zero future. Climate scenarios can help policymakers and financial institutions identify effective and efficient policies for emissions mitigation and carbon sequestration and indicate what measures particular goals would require.

Why Use Scenario Analysis?

Decision-makers can use scenario planning to consider the effectiveness of climate risk reduction and management measures, including both emissions mitigation and investment in adaptation and resilience. For example, cities facing increased heat stress could plant trees in high-traffic areas, increase the reflectivity of road and building surfaces, provide subsidies for low-income households to buy air conditioning, and provide more cooling centers for high-heat days. Areas facing projected increases in drought could select more drought-resistant crops, produce genetic innovation of seeds, evolve irrigation practices, and improve soil health practices. Together, adaptation interventions undertaken locally can stabilize the overall food production system.

Scenario analysis is an important tool for understanding and integrating climate risks and opportunities into a broader risk management framework. Scenario analysis is less about forecasting the most probable outcomes than it is a "what-if" analysis of different potential projections of the future. A common motto in the scenario planning world rings true—All climate scenarios are wrong, some are useful.

For example, practitioners can analyze scenarios that differ in their global trajectories of greenhouse gas emissions and atmospheric concentrations and thus pose different physical risks and damages from climatic disruption and ocean acidification. These scenarios can express the range of effects that different levels of radiative forcing would have on extreme weather events, sea level rise, agricultural productivity, public health, and other environmental and economic outcomes. Similarly, practitioners can analyze a low-carbon transition scenario in which the United States adopts an ambitious climate policy and compare it to a scenario—called a baseline, business-as-usual, or reference scenario—in which no new policies are adopted. In so doing, analysts gain insights into the potential outcomes (positive and negative) for individual assets, entities, or industries, as well as to the overall macroeconomy.[5]

Climate-related scenario analysis is gaining traction in several contexts, both domestically and internationally. Climate scenarios are being used within companies for internal decision-making; in analyses for disclosure of climate-related risks to investors and regulators; by banks and other financial institutions to assess individual investments and overall portfolios; and by financial regulators as discussed in Chapter 4. Each of these applications may require different scenarios that capture different risks. They may involve different modeling tools, underlying data, assumptions, and time scales. While useful, climate scenarios have limitations. The optimal design of climate scenarios will depend on the goals and methods of analysis. A wide variety of scenarios and of models to analyze the scenarios can be useful depending on the application.

What Are Climate Scenarios?

Temperature Scenarios

One common scenario design posits a future in which atmospheric concentrations of greenhouse gases are stabilized at a level at which global mean temperatures do not rise by more than a certain amount, such as 2 degrees Celsius above pre-industrial levels. Lower temperature targets require that greenhouse gas concentrations stabilize at lower levels,

[5] *One option for standardizing baseline projections would be to calibrate a model to a projection from the U.S. Energy Information Administration's Annual Energy Outlook. These projections, however, apply only to fossil fuel-related CO_2 emissions and thus would not include projections of other gases and sources in the United States.*

Figure 6.1: Relationships Between Transition Scenarios and Climate Risks

Green Scenario → High-Carbon Scenario

Scenario	Rapid Transition	Two-degree	Business-as-intended	Business-as-usual
Corrective transition response	Very strong	Strong	Substantial	Limited
Change in temperature vs. pre-industrial era (2100)	1.5°C	2°C	3°C	4°C

More Transition Risk

- Controlled yet aggressive change
- Major short-term impact but reduced long-term impact
- Lowest economic damage

More Physical Climate Risk

- Accelerating changes in earth system impacts
- Impacts continue to increase over time
- Economic damages increase

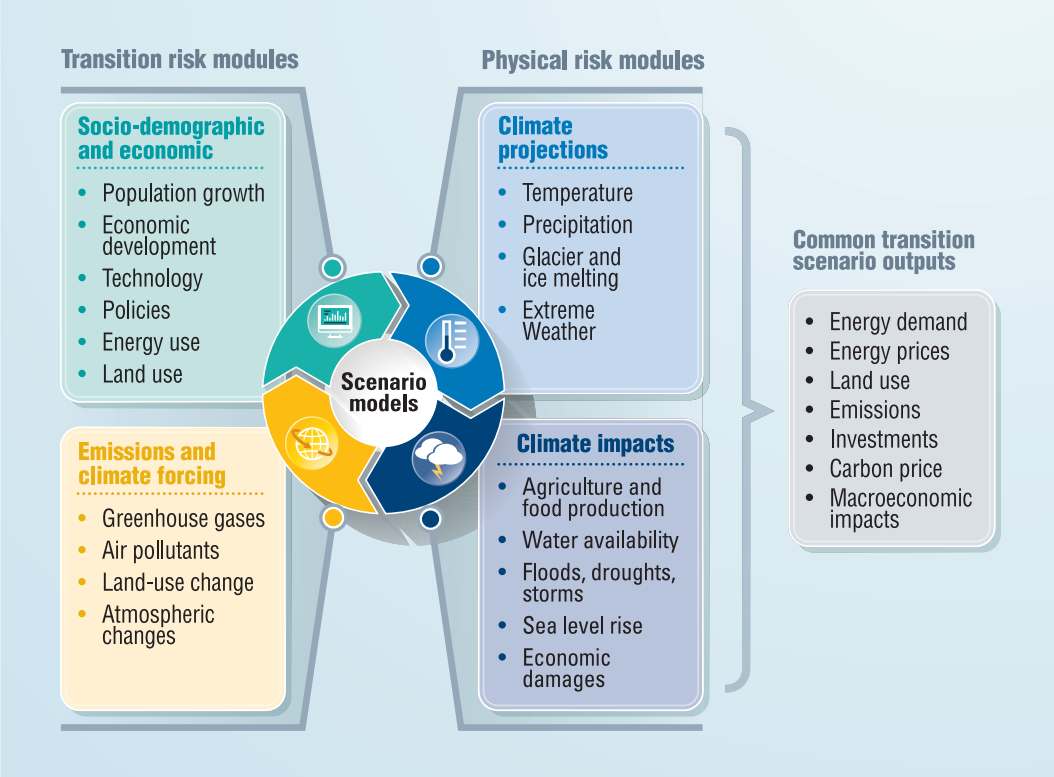
Note: "Business-as-intended" corresponds to Nationally Determined Contributions submitted under the Paris Agreement.

Source: Oliver Wyman (2019)

meaning that fewer net emissions can be emitted globally. Achieving a lower temperature target reduces the physical impacts of climate change but requires more aggressive and disruptive policies to achieve the necessary transition. As represented in Figure 6.1, a temperature scenario analysis can emphasize the physical climate outcomes, the policy outcomes, or both. Because temperature scenarios play out over at least several decades, they tend to involve longer-term projections of both physical and transition risks.

To study how the world can limit warming to a certain level, analysts specify a baseline policy, technology, and socioeconomic future. These scenarios generally include a set of assumptions that incorporate existing or planned global or regional policies, a business-as-usual sociodemographic projection, and projections for technological progress (including negative emissions and sequestration technologies), as highlighted by Figure 6.2. Scenarios can also incorporate disorderly or orderly transitions by specifying how gradually or sharply emissions fall. Policy scenarios specify government interventions that depart from the baseline—such as a carbon price trajectory or emissions limits—that then drive changes in the economy that reduce emissions. Depending on the kind of model and analysis, policy scenarios can apply economy-wide or to a subset of industries, for example just the power sector. In models of the global economy, scenarios can also apply internationally, allowing the investigation of spillovers across countries.

Figure 6.2: Representative Structure for Scenario Models



Source: Adapted from Potsdam Institute for Climate Impact Research (2018); Oliver Wyman.

In scenarios with no or limited emissions mitigation relative to business-as-usual, the likelihood and severity of major physical events will increase over time. These scenarios can encompass a broad range of impacts—including flooding, wind, heat, drought, and wildfire—or be restricted to physical risks of most concern to a given area.

Even under a 2 degrees Celsius scenario, the probability of major physical impacts will increase significantly over successive decades. If global mean temperature rises above 2 degrees Celsius, the probability of major physical impacts increases sharply, as does the probability that multiple perils impact a given region simultaneously. For example, without significant emissions abatement policies, the number of electric substations in Houston that would be exposed to acute flooding is forecasted to rise, significantly increasing risks for communities, chemicals plants, and oil and gas facilities (Jupiter Intelligence, 2020).

Event-Based Analysis

Event-based scenarios focus on the potential short-term impact of one triggering event, such as the sudden implementation of a major emissions regulation, a technological breakthrough, or an extreme weather event. Triggers can also include sharp changes in preferences, such as increased consumer demand for carbon-neutral products or the refusal of market actors to insure coal mines.

Event-based scenarios could be particularly useful for stress testing by firms and regulators because abrupt or disorderly outcomes may pose special risks for companies and the financial sector because the risks may not be priced into asset values. Modeling shorter-term, disorderly scenarios can also highlight the importance of near-term decisions in managing risks. Event-based scenarios are particularly appropriate for financial institutions. For example, an event scenario that specifies sea-level rise 30 years from now is not necessarily relevant to a trading company whose average risk duration is one year, but it is relevant to a potential mortgage investor.

Event-based analysis is also useful for modeling agricultural production. It allows for the management of short-term weather events within a growing season or annual variance in growing conditions. Decision-makers can then model the point at which the geographic scale, severity, or frequency of localized events collectively drive structural changes or risks to the overall system, informing policies that bolster food security.

Another important component of event scenario design is the potential for multiple simultaneous (and potentially uncorrelated) events—such as this year's sudden precipitous drop in oil prices as the COVID-19 growth shock was taking hold. Future examples could include a harvest shock in a breadbasket region of the world, which in turn could cause a spike in international food prices and trigger instability in food importing countries. In the face of multiple events, financial risks previously regarded as non-material could suddenly become material. In sum, plausible, relevant scenarios get risk managers' attention. This achieves the desired outcome of the event-based analysis: informing near-term decisions around managing climate risk.

Policy Pathways

To analyze the implications of achieving a given emission or concentration target, modelers run "solve-to-match" scenarios in which they estimate the carbon prices or other policy features that would be consistent with achieving a goal. For example, modelers may estimate the greenhouse gas (GHG) price trajectory that, when applied globally, stabilizes atmospheric concentrations of GHGs at a particular level. Alternatively, a climate policy scenario may reflect the actual policies countries are implementing or plausibly could implement. In that case, modelers would simulate different policies in different countries. For any given country, these scenarios may be much less stringent than those that achieve a temperature target of 2 degrees Celsius or less.

Policies can have both near-term and long-term impacts on the economy and the environment. Outcomes of interest to policymakers and stakeholders include policy impacts on prices, economic growth, structural changes in the energy system and other sectors, household welfare, trade, government revenue, and investment. Like any modeling, the further out the projection, the greater the uncertainties. Thus, modelers often caution policymakers to focus on comparisons across scenarios and the direction of change rather than point estimates within one scenario's results.

Plausibility

Finally, climate scenarios should be both *plausible* and *relevant*, all the while informed by climate science. For physical risks, plausibility comes first and foremost from being based squarely on the latest climate science. Transition policies may vary considerably in their ambition. Because any number of changes in policies and market actor behavior are plausible, regulators should offer a range of climate scenarios. Relevance comes from ensuring that scenarios' time frames and impacts are material to an institution's business.

Limitations of Scenario Analysis

While useful, climate scenarios and the models that analyze them have limitations: they are sensitive to key assumptions, most have been developed for purposes other than financial risk analysis, and they cannot fully capture all of the potential effects of climate- and policy-driven outcomes. Like many modeling exercises, climate scenario outcomes are sensitive to key assumptions and parameters, such as the rate of technical change.

For example, the Intergovernmental Panel on Climate Change (IPCC) projects that substantial deployment of negative emissions technologies, such as biomass energy with carbon capture and storage (CCS), would be required to achieve a 1.5 degrees Celsius outcome, and many analyses draw similar conclusions about reaching 2 degrees Celsius. The cost and availability of such technologies has an enormous effect on the estimated price of carbon that would be required to deploy them. Models that assume the availability of low-cost CCS, battery storage, hydrogen fuel cells, or other as-yet-nascent technology will project that the requisite carbon taxes, cap and trade systems, or other policy measures to achieve stringent goals can be modest.

Likewise, models that assume limited availability of low-cost low- or negative-carbon technologies will project that the policies to achieve ambitious temperature targets will be quite costly. Understanding these sensitivities and considering multiple scenarios is useful not only to put the results in relative perspective, but also to motivate policies to promote technological development.

Most climate scenarios are intended for a purpose other than financial risk assessment. For example, the modeling studies assessed in IPCC reports typically involve energy-economy-climate models used for policy analysis and research applications. They may report high-level results, such as shifts in fuel sources, but not critical outputs for financial analysis such as the number of electric vehicles on the road. Future enhancements could include more-detailed models, further calculations to generate new relevant variables, and models that better represent the direct and indirect transmission channels through which physical and transition risk could affect financial outcomes (NGFS, 2020a).

Finally, models cannot fully capture the range of how market actors will respond to climate change, how their responses will affect climate change, and how they will influence policies around climate change. As the climate continues to change, decision-makers will respond in ways that can both create and alleviate risks. Damages from climate change may be lower with appropriate adaptation and risk management—or substantially higher if potential low-probability but high-impact risks materialize. Market actor and policymaker responses are complex and should be considered qualitatively along with a quantitative scenario analysis. Some of these limitations are inherent to many models but are in this case further exacerbated by the often-multi-decade time horizon and the complexity and interdependencies of the effects modeled, from ice sheet melting to agricultural yields and migration. To mitigate the limitations of scenarios and modeling, practitioners should analyze multiple scenarios with various underlying assumptions and parameters.

Practical Applications of Scenarios

Climate Scenarios and the Role of Regulators

Climate risk is in part a manifestation of the failure of the current economic system to price externalities and capture them in current accounting, performance measurement, and incentive systems. Scenarios help elucidate the nature of the externalities and translate climate risk into financial risk. Climate risk derives in part from a lack of policies, like a price on carbon, that would internalize the external costs of damaging emissions, but it also comes from traditional accounting practices that ignore these externalities and the prospect of their regulation. This mispricing naturally leads to the misallocation of capital, including the continuing distortions in energy systems that promote climate change.

Financial regulators around the world are aware of this misallocation and mispricing and some are adopting policies to address it. They do not have the authority to directly regulate emissions, but they can, through their financial stability objectives, promote climate risk management—which in turn can facilitate the orderly transition to a net-zero economy. Scenario analysis is an important tool that regulators can use to encourage climate risk management: Have you thought about these risks? Have you discussed them with your clients? What are you doing about it?

Climate Scenarios in the Context of Financial Stress-Testing (UNEP FI and Oliver Wyman, 2018)

Clear parallels exist between macro-economic stress testing and climate scenario analysis. Both use scenarios and are undertaken to estimate a firm's level of risk. Despite these high-level similarities, macro-economic risk and climate risk assessment have several significantly different features. The scope, time frame, and use of risk assessment exercises vary widely.

Since the 2008 global financial crisis, the term "stress testing" has generally been used to qualify a comprehensive, firm-wide scenario analysis. In such analyses, most elements of the profit and loss statement and balance sheet are estimated under a set of macro-economic scenarios designed to test the bank's resilience to a specific shock. Macro-economic stress testing is generally used in a regulatory context for the purpose of estimating capital needs and planning capital management for a period of two to five years.

In contrast, climate scenario analysis is not primarily a capital management exercise. Where macro-economic stresses are assumed over a period of only a few years, climate-related risk evolves over decades, though policymaker, consumer, and investor climate-related preferences could change much more abruptly.

In our view, the primary purpose of climate stress testing is to understand and evaluate the sensitivity of a bank's current portfolio to climate scenarios. Capturing projected impacts on the current business profile can facilitate strategic planning and portfolio construction. In other words, climate scenario analysis is more a "what-if" analysis under different transition and physical scenarios rather than holistic stress testing exercise as undertaken for modern capital management analyses.

For instance, the Bank of England's Prudential Regulation Authority (PRA) has imposed supervisory expectations on climate risk management. The expectations include incorporating risks related to climate change into the risk management framework, raising the issue to the board-level, and performing climate scenario analysis. By focusing on enhanced disclosure, the TCFD is also aiming to influence the allocators of capital by enabling the market to better price these risks (TCFD, 2017).

Central banks and regulators—including the Central Banks and Supervisors Network for Greening the Financial System (NGFS)—are also moving ahead on climate risk management and scenario development (Vaze, 2019; NGFS, 2020b). The NGFS provides practical advice on scenario analysis, along with eight high-level climate scenarios (NGFS, 2020c) and detailed technical documentation and modeling data (NGFS, 2020d). The scenarios reflect different projections of future temperature targets, policies, technology development, and climate damages with an eye to providing a foundation for decision-useful analysis by both governments and private sector actors.

Should Institutions Use a Common Set of Climate Scenarios?

Both common and tailored scenarios are useful. From a practical perspective, it makes sense for practitioners and risk managers to converge on a common menu of scenarios. It would allow better comparability across results and encourage the development of universal scenario analysis capabilities. Policymakers and regulators, in consultation with experts and stakeholders, should develop and prescribe a consistent and common set of scenarios and assumptions, which will help align the collective action necessary to mitigate climate risk. Common scenarios render best practices transparent, minimize gaming, and serve to raise the collective bar. Internationally and domestically, alignment of scenarios across industry and regulatory bodies would also prove beneficial.

However, since policies and climate effects depend on location, it makes sense to customize the basic scenario frameworks with parameters that work for a particular context. For example, a common policy scenario design could specify an economy-wide carbon tax trajectory, but the pertinent initial values and the rate of change in the tax may differ from country to country.

While establishing a set of common standards would clearly be useful, over reliance on one model or scenario may generate systemic issues. It is therefore important that institutions go beyond running prescribed scenarios and use additional scenarios tailored to their exposures and vulnerabilities. By going beyond a pure compliance exercise, tailored scenarios will maximize the benefit for the institutions. Climate scenario analysis can inform adjustments to their risk management practices and improve their decision making more broadly.

Having common and tailored scenarios in place is not dissimilar to the stress testing exercises established during the financial crisis. Regulators deployed a set of scenarios to build investor confidence in the banking system and later also required institutions to run their own scenarios. Once armed with climate scenario modeling capabilities, institutions will naturally be able to run scenarios more tailored to their business needs.

Recommendations

Scenarios and Scenario Analysis

Climate scenario analysis should focus on potential material impacts to the institution's financial portfolio, whether loans, derivatives, or investments. In this context, the following guidelines should be useful:

Recommendation 6.1: Analyze more than one warming path. Various long-term paths for climate change exist and can be used for scenario analysis. Three common scenarios are (i) Paris-aligned (for example, consistent with limiting temperatures well below 2 degrees Celsius above pre-industrial levels), (ii) current trajectory and (iii) in-between (for example, late policy adoption with a more abrupt and disruptive response). Each will produce different impacts on institutional portfolios and provide insights that will help to more effectively manage risk, particularly bookends of best- and worst-case scenarios. Scenarios should include both shorter- and longer-horizon paths as appropriate.

Recommendation 6.2: Analyze disruptive policy. It is particularly important to analyze a scenario involving a major policy disruption. Transition scenarios have wide implications across the economy, industries, and markets. Unanticipated policies can abruptly strand long-lived capital assets or induce rapid reallocation of capital across sectors and industries. Increasing physical impacts may increase the risks of a disorderly transition as fires, floods, and hurricanes, and the attendant shifts in public sentiment, force governments into unanticipated policy responses. Scenarios are therefore especially relevant for risk management.

Recommendation 6.3: Analyze both broad and specific impacts. Scenarios should capture the breadth of impacts but with a focus on materiality, covering a global perspective but enabling regional, country, and sectoral analysis appropriate to the firm's business.

Recommendation 6.4: Map macroeconomic and financial impacts. Scenarios should take into account macroeconomic and financial outcomes since these are likely to be most material to financial institutions. Coming up with additional temperature scenarios, for example, is less important than providing some common guidance on potential transmission mechanisms and implications for macroeconomic and financial factors.

Recommendation 6.5: Account for adaptation actions to the extent feasible. Tackling climate change necessarily involves myriad adjustments by a range of actors. Modeling the effects of such adaptation actions on portfolios is complex but may become more feasible with future technology and scenario modeling development.

Policymakers and Regulators

Recommendation 6.6: Prescribe a consistent and common set of broad climate risk scenarios, guidelines, and assumptions and mandate assessment against these scenarios, as described in Chapter 4. Regulators, in consultation with industry participants, external experts, and other stakeholders, should develop and prescribe a consistent set of broadly applicable scenarios, guidelines, and assumptions and require institutions to assess their exposure to those scenarios. Climate scenarios should be both plausible and relevant, all the while informed by climate science. Regulators should require a range of climate scenarios, including scenarios covering severe but plausible outcomes. Key assumptions (including policy pathways) and limitations should be transparent. Scenarios, assumptions, and guidelines should be updated as relevant factors are better understood and as policy and technology evolve. There should be a recognition that climate risk will manifest differently across various parts of the financial system.

Recommendation 6.7: Provide analytical discretion, to the extent practicable, as long as regulatory needs for consistency and comparability are met. Given the many unknowns and complexities inherent in modeling the economy, climate change science, and policy, regulated entities will need some discretion in how they perform their analysis based on the prescribed scenario. On the other hand, regulators need consistent approaches across firms so they can ensure risks are responsibly analyzed and reported. Investors would benefit from better comparability across scenario-related disclosures. To achieve a balance across these needs, regulators, in consultation with the firms they regulate, should specify key assumptions, scope, and the outputs they expect. As long as regulators' prescribed expectations are satisfied, regulators should allow financial institutions to provide additional context and analysis informed by the nature and complexity of their business.

Recommendation 6.8: Encourage domestic and global coordination across regulators to provide a coherent approach. This is an overarching theme of this report and especially applicable to the use of scenarios for risk management. Requiring entirely different stress scenario exercises from institutions operating under different jurisdictions would be costly while generating uncertain value. Harmonizing requirements and prioritizing practical, actionable exercises where feasible would be useful. The high costs associated with multiple regulatory regimes is a lesson of post-financial crisis regulation that can be applied now to climate risk.

Recommendation 6.9: Focus on materiality and risk management. Climate risks can manifest in many different ways. Institutions should focus on what matters for them and what decisions need to be made given their specific exposures and vulnerabilities. Such an approach facilitates effective risk management by laying out plausible ways climate risk-related financial losses could occur.

Recommendation 6.10: Ensure a mechanism for ongoing refinement and improvement. As science, data, tools, conditions, and policy change, it is important for regulatory guidelines to evolve as well. Data in particular is evolving rapidly. Creating a mechanism for regular updating, rather than relying on ad hoc adjustments, would be beneficial to ensure effective and pragmatic oversight. As regulators better understand the material risks in the system and their spillover effects across industries and markets, a mechanism for ongoing learning and timely refinement from these lessons learned will ensure they are most effectively managing risk across the system.

Capabilities and Applications

Given the uncertain nature of how the climate will evolve and the limited ability to rely on historical data and back-testing, robust scenario analysis calls for a new set of capabilities that combines statistical, financial, and environmental knowledge.

Recommendation 6.11: Tailor analysis to specific exposures. How an institution analyzes scenarios should be determined based on the unique nature of its portfolio. Not every scenario will be material to an institution's portfolio, depending on its largest asset concentrations, longest-dated assets, and highest potential sensitivities.

Recommendation 6.12: Use results to upgrade risk management capabilities. Regulators and risk managers can use insights coming from scenario analyses to strengthen and augment existing institutional risk management. Each institution should determine how to do so within its own framework but could include climate-related limits, adjustment to underwriting processes, client engagement, and climate risk appetite.

Recommendation 6.13: Beware of false precision. Scenario analysis can provide great value in understanding a range of potential outcomes (particularly between worst and best cases) and in identifying concentrations and relative sensitivities in a portfolio. But results, especially quantitative ones, will be illustrative, not precise, and so should be used accordingly in risk management decisions.

Risk Managers

Recommendation 6.14: Risk managers should develop in-house capabilities, as relevant and in line with best practices, to analyze climate scenarios, understand the key underlying assumptions, and recognize the limitations.

Recommendation 6.15: Firms and institutions should consider additional climate scenarios, guidelines and assumptions tailored to their specific needs and vulnerabilities, in addition to those provided by policymakers and regulators, to enhance internal risk management and decision-making. This can focus on generating decision-useful information for identifying and managing climate risk given their specific exposures and vulnerabilities.

Recommendation 6.16: The scope, depth, and complexity of the analyses performed by institutions should be proportionate to the materiality of the impact measured.

Chapter 7

A Closer Look at Climate Risk Disclosure

As earlier chapters of this report have shown, the physical and transition risks of climate change are increasingly material to firms, investors, and the U.S. economy. When climate-related issues materially impact a firm's underlying operations and capital investments, the firm's financial statements should address them. When these issues pose material risks to firms, other sections of financial filings, such as Management's Discussion and Analysis, Risk Factors, and Description of Business (collectively, MD&A), should address them.

As the physical and transition risks of climate change have manifested with greater intensity and frequency, it has become increasingly clear that these risks affect capital markets writ large. The Sustainability Accounting Standards Board (SASB) finds that industries totaling 93 percent of U.S. market capitalization are materially exposed to climate risk (SASB, 2016). As firms, investors and other capital market actors seek to make informed decisions in the face of these risks, demand is growing among market stakeholders for comprehensive disclosure evaluating climate-related risks and uncertainties.

Climate risk disclosure offers a variety of potential benefits to issuers, investors, and society. For issuers, potential benefits include the improved ability: (i) to identify, assess, manage, and adapt to the effects of climate change on operations, supply chains and customer demand; (ii) to relay risk and opportunity information to capital providers, investors, derivatives customers and counterparties, markets, and regulators; and, (iii) to learn from competitors about climate-related strategy and risk management best practices. Peer group disclosures create an information platform where companies can learn from each other and, as a result, increase their organizational and network resilience.

For other market actors, the benefits of comprehensive climate disclosure are several. Investors can better assess a more refined measure of the long-term cost of capital, as well as risks to firms, margins, cash flow and valuations. In addition, investors and society can gain greater assurance that issuers take these risks seriously. In the absence of robust disclosure, market participants may presume that a company is unprepared for climate-related risks, especially at a time of heightened volatility, such as during an extreme climate-attributed event. Ultimately, a lack of disclosure could also affect market confidence in management, valuation multiples and the cost of capital.

By building on the firm-level disclosures provided by issuers, U.S. financial regulators would be better able to understand the impacts of climate change on financial markets. This greater understanding would allow them to issue relevant guidance or regulation needed to improve the resilience of financial markets in the face of this risk and uncertainty. By the same token, state and local governments—and community members themselves—would be better able to understand how companies in their localities are preparing for climate risks and opportunities that could impact the local economy, labor force, and tax base.

The Current State of Climate-Related Disclosure

Disclosure frameworks have been developed to enhance the quality and comparability of corporate disclosures. Examples include CDP (formerly, the Climate Disclosure Project), the Climate Disclosure Standards Board (CDSB), the Global Reporting Initiative (GRI), the International Integrated Reporting Council (IIRC), the Sustainability Accounting Standards Board (SASB), and, most notably, the Task Force on Climate-related Financial Disclosures (TCFD). The TCFD recommendations have been integrated into several of the other frameworks. Many of these organizations, together with accounting and standardization groups, have formed the Corporate Reporting Dialogue to strengthen cooperation, coordination, and alignment among key standard setters and framework developers (CRD, 2019).

Investors and financial market actors have recognized this need and have long called for "decision useful" climate risk disclosures (CalPERS, et al., 2007). In 2019, 631 investors managing more than $37 trillion signed the *Global Investor Statement to Governments on Climate Change*, which called on world governments to improve climate-related financial reporting. The statement specifically called on governments to "commit to implement the TCFD recommendations in their jurisdictions, no later than 2020" (IAFP, 2019). As noted by the TCFD:

> There is a growing demand for decision-useful, climate-related information by a range of participants in the financial markets. Creditors and investors are increasingly demanding access to risk information that is consistent, comparable, reliable, and clear. There has also been increased focus, especially since the financial crisis of 2007-2008, on the negative impact that weak corporate governance can have on shareholder value, resulting in increased demand for transparency from organizations on their risks and risk management practices, including those related to climate change (TCFD, 2017, p. 1).

In response to market participants' informational needs, the number of entities disclosing climate-related information has increased, and the quality of the disclosed information has improved over the past several years (Ohm, et al., 2020). Yet, despite this progress, the information disclosed falls significantly short of what capital market actors need to adequately integrate climate risk into their decision-making (TCFD, 2019a).

Table 7.1: Sample of Leading Voluntary Frameworks	
CDP	CDP issues an annual global questionnaire that collects information on climate change and other sustainability issues to help organizations measure and manage these risks and opportunities.
Climate Disclosure Standards Board (CDSB)	The CDSB Framework provides guidance on how and what to report on climate and other environmental issues in a mainstream annual report.
Global Reporting Initiative (GRI)	The GRI Standards outline how and what to report regarding the material economic, social, and environmental impacts, such as climate change of an organization on sustainable development. The GRI Standards can be used in sustainability reports, as well as in annual or integrated reports. It is oriented at a broad range of stakeholders.
Integrated Reporting (IR)	The International Integrated Reporting Council (IIRC) has developed a reporting framework that explains how an organization can report on the value it creates for itself and others. Reporting on the basis of the framework results in an integrated annual report or in a separate integrated report, and the main audience is providers of financial capital.
Sustainability Accounting Standards Board (SASB)	SASB's Standards guide reporting on financially material environmental, social and governance issues by means of indicators (called metrics) and disclosures for 77 industries. Its main use is intended to be in the communications to investors, such as the annual report, and it has the objective of informing financial stakeholders.
Task Force on Climate-Related Financial Disclosures (TCFD)	Established by the Financial Stability Board, the TCFD developed voluntary, consistent climate-related financial disclosures, building on existing disclosure regimes to develop a singular, accessible framework. The TCFD developed four widely adoptable core recommendations on climate-related financial disclosures of universal applicability to organizations across sectors and jurisdictions, divided into these topics: governance, strategy, risk management, and metrics and targets.

The widespread use of these frameworks underscores that collecting, assessing, and disclosing climate risk information is a practical process, in which most large companies are already engaged. Table 7.1 shows a range of active frameworks. In 2020, 515 investors with $106 trillion in assets and 147-plus large purchasers with more than $4 trillion in procurement spending have requested thousands of companies to voluntarily disclose their environmental data through the CDP. More than 7,000 companies globally use the CDP questionnaire (CDP, 2020). More than 10,000 reporting organizations across 90 countries use GRI instrumentation (GRI, 2019), including 74 percent of the largest 250 corporations (GRI, 2020). More than 100 companies have adopted SASB standards (SASB, 2020). Finally, 785 companies have committed to support the TCFD and many already disclose in accordance with at least some of the TCFD's recommendations (TCFD, 2019a).

Task Force on Climate-Related Financial Disclosures

To accelerate global collaboration to improve climate disclosure, the TCFD was established by the Financial Stability Board at the request of Group of Twenty (G20) nations in 2015 to develop recommendations to help financial market participants understand their climate-related risks. Made up of 26 members representing investors and companies from a range of industries, the Task Force developed 11 recommended climate-related disclosures across four broad areas: governance, strategy, risk management, and metrics and targets. Central to the TCFD's recommendations is the application of forward-looking scenario analysis, which the TCFD states is critical for understanding the strategic implications of climate-related risks and opportunities.

The TCFD's recommendations apply to corporations in financial and non-financial industries, asset owners, and asset managers. The recommendations form a strong foundation for use by securities regulators as the basis for climate disclosure rules. They are based on existing regulatory reporting requirements related to material risk disclosure, including climate risks, as well as the work of CDP, CDSB, GRI, IIRC, SASB and others. Table 7.2 highlights the TCFD's principles for effective disclosure.

Table 7.2: Principles for Effective Disclosures

1	Disclosures should represent relevant information
2	Disclosures should be specific and complete
3	Disclosures should be clear, balanced, and understandable
4	Disclosures should be consistent over time
5	Disclosures should be comparable among companies within a sector, industry, or portfolio
6	Disclosures should be reliable, verifiable, and objective
7	Disclosures should be provided on a timely basis

Source: TCFD (2017)

At the same time, the slow rate of growth in the number of firms and other market participants disclosing under the current disclosure regime, which relies to a large extent on voluntary disclosures by companies and other market participants, is not sufficient to meet investor needs, given the urgency of mitigating and adapting to climate change. The TCFD's most recent status report included a review of reporting by more than 1,100 companies from 2016 to 2018, and found that, while disclosure rates were increasing, surveyed companies only made, on average, 3.6 of the 11 total TCFD recommended disclosures (TCFD, 2019b). An analysis of Russell 3000 companies found that 30 percent discussed climate change as a risk in their 10-K filings, but only 3 percent of companies discussed climate risks in the MD&A section of those filings (Rozin, 2019).

Large companies are increasingly disclosing some climate-related information, but vary significantly in the specific information they disclose, presenting a challenge for investors and others seeking to understand exposure to and management of climate risks. The TCFD found variations across its 11 recommended disclosures. For instance, climate disclosure rates varied from as low as 9 percent for one of its recommended disclosures to as high as 47 percent for another disclosure (TCFD, 2019b). In many industries, it is challenging to determine how a company is exposed to climate-related risks in its value chain (Bolton, et al., 2020). Progress has been made in classifying emissions impacts into Scope 1, 2 and 3 emissions, which allows for a risk assessment to evaluate potential weaknesses throughout the value chain (Bolton, et al.). Chapter 5 addresses Scope 3 emissions and transition risk in greater detail.

For all industries in which climate risk is material, the lack of comprehensive and comparable disclosure not only poses a challenge to investors seeking to assess, manage, and mitigate climate risk, but it also impedes the ability of disclosing organizations to inform their strategic responses to climate risk by benchmarking their performance against peer organizations.

To illustrate the point, a U.S. Government Accountability Office (GAO) report provides examples of two contrasting disclosures, with excerpts from U.S. Securities and Exchange Commission (SEC) filings (GAO, 2018). The GAO characterized the first example as containing boilerplate and unquantified information, and the second as containing some quantitative information and metrics.

The first example states, in part, that:

> [c]limate change initiatives may result in significant operational changes and expenditures, reduced demand for our products and adversely affect our business … We assess, monitor and take measures to reduce our carbon footprint at existing and planned operations. We are committed to complying with all Greenhouse Gas [(GHG)] emissions mandates and the responsible management of GHG emissions at our facilities (GAO, 2018, p. 35).

By contrast, the second example states:

> Examples of legislation or precursors for possible regulation that do or could affect our operations include: European Emissions Trading Scheme [(ETS)], the program through which many of the European Union [(EU)] member states are implementing the Kyoto Protocol. Our cost of compliance with the EU ETS in 2015 was approximately $0.4 million (net share pre-tax). … Carbon taxes in certain jurisdictions. Our cost of compliance with Norwegian carbon tax legislation in 2015 was approximately $31 million (net share pre-tax)(GAO, 2018, p. 36).

The disclosing firm goes on to highlight concrete actions in response to the risks:

> The company has responded by putting in place a corporate Climate Change Action Plan, together with individual business unit climate change management plans in order to undertake actions in four major areas: … Reducing GHG emissions—In 2014, the company reduced or avoided GHG emissions by approximately 900,000 metric tonnes by carrying out a range of programs across a number of business units. … The company uses an estimated market cost of GHG emissions in the range of $8 to $35 per tonne depending on the timing and country or region to evaluate future opportunities (GAO, 2018, p. 36).

These examples highlight the great disparity between intent and disclosure quality. Given the disparity in the quality and extent of disclosures under the existing regime, clearer and more consistent guidance as well as mandatory disclosure requirements may be needed for climate risk disclosure that covers materiality assessments.

U.S. Legal Authorities and Practices Related to Climate Risk Disclosure

This section complements the discussion of authorities in Chapter 4. It provides additional detail of existing legislation, regulations, and practices in climate risk disclosure, as well a discussion of the key barriers to more effective climate risk disclosure.

Publicly Traded Corporations

In the United States, the SEC's Regulation S-K provides disclosure requirements for publicly traded firms. They are required to disclose, through annual or other public filings, known trends, events, or uncertainties that are "reasonably likely to have a material effect" on the firm's financial condition or operating performance. Information is material if there is a substantial likelihood that a reasonable investor would consider it important in making an investment decision.

In response to a petition from 22 institutional investors and other organizations managing more than $1.5 trillion in assets, the SEC in January 2010 published, *Commission Guidance Regarding Disclosure Related to Climate Change* (the *SEC Guidance* or *Guidance*). It interprets SEC disclosure requirements, as they apply to business or legal developments relating to climate change (SEC, 2010). In addition to the review of the applicability of requirements under Regulation S-K to climate risks, the *Guidance* also discussed several topics that represent "some of the ways climate change may trigger disclosure required by these rules and regulations" and which "a registrant may need to consider" (SEC, 2010, p. 22). These include the impacts of legislation and regulation, international accords, indirect consequences of regulation or business trends, and the physical risk of climate change.

The SEC *Guidance* discussed disclosure requirements applicable to material climate risks: Description of Business, Legal Proceedings, Risk Factors, Management's Discussion and Analysis, and Foreign Private Issuers. The *Guidance* also addressed disclosure in financial statements, where the SEC noted that "[i]n addition to the Regulation S–K items discussed in this section, registrants must also consider any financial statement implications of climate change issues in accordance with applicable accounting standards, including Financial Accounting Standards Board [(FASB)] Accounting Standards Codification Topic 450, Contingencies, and FASB Accounting Standards Codification Topic 275, Risks and Uncertainties" (SEC, 2010, p. 22).

The Sarbanes-Oxley Act of 2002 also set out requirements related to corporate disclosure that have resulted in rulemaking by the SEC. Section 302 of the law discusses disclosure controls, including the requirement to establish, maintain, and regularly evaluate the effectiveness of the issuer's disclosure controls and to have corporate officers certify that such controls are in place (SEC, 2002). Building on this, Exchange Act Rules 13a-14 and 15d-14 require that the issuer's principal executive officer and principal financial officer certify that the financial statements and other financial information included in the report do not omit a material fact. The purpose of the rules is to avoid misleading quarterly and annual reports and ensure the fair presentation in all material respects of the financial condition, results of operations and cash flows of the issuers.

To the extent climate risk is material to an issuer, Section 302 of Sarbanes-Oxley applies. The SEC's 2010 climate disclosure guidance points this out and discusses management's obligation, when determining materiality, to "consider all relevant information even if that information is not required to be disclosed" and "consider whether they have sufficient disclosure controls and procedures to process this information" (SEC, 2010, p. 19).

The impact of the 2010 *Guidance* has been limited. A report by the GAO found that "[c]limate-related disclosures vary in format because companies may report similar climate-related disclosures in different sections of the annual filings," which may result in "SEC reviewers and investors [finding] it difficult to navigate through the filings to identify, compare, and analyze climate-related disclosures across filings..." (GAO, 2018, p. 19). The report

also found that "climate-related disclosures in some companies' filings use boilerplate language, which is not specific to the company, and information is unquantified," thereby limiting the utility of the information to investors (GAO, 2018). While the SEC has not updated the guidance since it was issued in 2010, global expectations for increasingly sophisticated and robust climate risk disclosure in financial filings have grown.

The quality of climate disclosure in the United States by issuers largely remains inadequate for the needs of investors (Mahoney and Gargiulo, 2019). Disclosure in SEC filings has been inadequate, in part, because materiality under U.S. law is often interpreted as limiting required disclosure to short- and medium-term risks, and firms may have assumed that climate risks are relevant only over longer time horizons. However, different firms and industries may have different time horizons over which climate risks are deemed material, taking into account factors like the economic life of assets, the percentage of valuation that can be attributed to future growth, the nature of climate-related risk exposure, and corporate strategy. Physical risk exposure of a company or industry may fall somewhere between near-term acute shocks and long-term chronic stresses. These factors should be evaluated when determining which climate risks—including medium- to long-term transition risks—are material and should be included in SEC filings.

Moreover, even in the case of long-term physical and transition risks, investors have asked the SEC to consider the perspective of shareholders investing for the long-term benefit of their beneficiaries. For example, the California Public Employees' Retirement System (CalPERS), the second largest pension fund in the United States, "urge[d] the SEC" to consider improvements to its disclosure regime, including "clarifying the definition of materiality to reflect long-term investor needs" (Hoffner, 2016). Guidance published by BlackRock (the largest asset management firm in the United States) and CalPERS for engaging the companies they own make clear their emphasis on long-term value creation and their need for climate risk disclosures to ensure that value is sustained (CalPERS, 2019; Fink, 2020).

Municipal Securities

The Municipal Securities Rulemaking Board (MSRB) and the Financial Industry Regulatory Authority (FINRA) oversee the municipal securities market. Rules require that underwriters in most municipal securities offerings ensure that municipal issuers make information about themselves and their securities available both at the time of the offering and on an ongoing basis. Voluntary guidelines for primary and ongoing municipal bond disclosure, such as those promulgated by the Government Finance Officers Association (GFOA) and the National Federation of Municipal Analysts (NFMA), emphasize that issuers should provide information necessary to ensure a clear understanding of their condition (NFMA, 2019; GFOA, 2020).

Congress and the SEC oversee the MSRB, and its rules generally must be approved by the SEC before becoming effective. The MSRB is not responsible for enforcing its rules or conducting compliance examinations. The SEC, federal financial regulators, and FINRA

share responsibility for enforcement and compliance examinations in the municipal securities market. In 2010, Congress broadened the MSRB's mandate to include protection of state and local governments and other municipal entities, and extended the jurisdiction of the MSRB to include the regulation of municipal advisers. The MSRB's Electronic Municipal Market Access (EMMA) website aims to protect investors and municipal entities in the municipal market by increasing the transparency and availability of market information, including offering documents, official statements, and continuing disclosures.

To date, municipal regulators and the bodies that oversee them have not issued guidance or rules related to climate risk disclosure for municipal bonds. Two reports have examined applicable disclosure laws and examples of municipal securities disclosure and found climate risk disclosure to be inadequate (Rhodes and Magrini, 2019; Hamilton, 2010). However, the SEC's stance appears to be evolving. At a 2018 SEC municipal securities disclosure conference, the director of the SEC's Office of Municipal Securities asked attendees how market participants were grappling with climate risk. Several panels discussed disclosure of extreme weather events and climate risks, with speakers noting increased investor demand for climate-related information (Olsen, 2018; SEC, 2018).

Federal Government Entities

The federal government also could strengthen disclosure practices for its own portfolio of assets. The Federal Accounting Standards Advisory Board (FASAB) issues federal financial accounting standards and guidance. FASAB guidance covers the annual Financial Report of the United States Government, as well as disclosure specific to federal departments, agencies and administrative units. In fiscal year 2019, the federal government collected $3.6 trillion in taxes and other revenues, had a net cost of $5.1 trillion, and had a balance sheet with $4 trillion in assets and $27 trillion in liabilities (Treasury, 2020). Thus, its disclosure of climate risk could be substantial. The federal government may be able to advance innovation in the measurement and disclosure of climate risks across the wide variety of asset classes that the federal government owns and manages. These innovations may reciprocally support disclosure practices and guidance among state and local governments, as well as the private sector.

Global Climate Risk Disclosure Developments

Climate disclosure has become increasingly important to foreign financial regulators as recognition has grown that climate risks can have significant effects on financial systems. Foreign regulators increasingly recognize that they can do more to both ensure the stability of capital markets in the face of these risks and enable market actors to assess and mitigate the risks. This recognition is coming not only from securities regulators, but also from central banks, prudential supervisors, accounting and auditing overseers, and other regulators.

A consensus is growing among regulators that disclosure, as an important element of a climate risk management strategy, helps market participants better understand and act on the climate risks that they face, and provides comparable information that benefits investors, regulators, and other stakeholders. The International Organization of Securities Commissions (IOSCO), whose members represent 115 countries and more than 95 percent of the world's securities markets, has stated, "[s]ecurities market regulators have a key role to play in reminding issuers to consider such risks and to disclose material ESG [(environmental, social and governance)] information to investors" (IOSCO, 2019, p. 3). IOSCO has several workstreams to advance this disclosure.

Several foreign financial regulators have recently put forward or are exploring rules for climate risk disclosure, which could act as models to be adapted for the U.S. context. The European Commission (EC) adopted *Guidelines on Reporting Climate-related Information* in June 2019. The guidelines structure the proposed climate-related disclosure into five reporting areas: (i) business model; (ii) policies and due diligence; (iii) outcome of policies; (iv) principle risks and risk management; and, (v) key performance indicators (EC, 2019). Article 173 of France's Energy Transition Law lays out climate disclosure requirements for both listed companies and investors. The regulation uses a "comply or explain" approach that provides flexibility for how firms disclose their risks. Additionally, Article 173 calls for an assessment of reporting progress made during its first two years. This review may lead to more explicit guidance on reporting methodologies. Similar models are being explored by Spain and Sweden, among others.

The United Kingdom's *Green Finance Strategy* called on all listed companies and large asset owners to disclose in line with the TCFD recommendations by 2022 (HM Government, 2019). The strategy also announced that the U.K. government will form a task force to examine potentially effective disclosure approaches, including climate disclosure rules. In 2019, the final report of Canada's Expert Panel on Sustainable Finance proposed that Canada adopt the TCFD recommendations on a "comply or explain" basis (Canada, 2019). Additionally, in 2019, the Canadian Securities Administrators (CSA) issued guidance on how issuers could more effectively disclose their material risks, opportunities, financial impacts, and governance processes relating to climate change (CSA, 2019).

The International Financial Reporting Standards (IFRS) Foundation published a mapping exercise discussing when it would be appropriate for companies to disclose climate issues according to the following IFRS standards: (i) Presentation of Financial Statements; (ii) Impairment of Assets; (iii) Property Plan and Equipment; (iv) Intangible Assets; (v) Fair Value Measurement; (vi) Financial Instruments; and, (vii) Provisions, Contingent Liabilities and Contingent Assets (Anderson, 2019). The Australian Accounting Standards Board and Auditing and Assurance Standards Board discussed the potential financial implications of climate risks that issuers should consider, such as changes in the useful life of assets, changes in the fair valuation of assets, and changes in expected credit losses for loans and other financial assets (AASB and AUASB, 2019).

The Case for Regulatory Action

Given the inadequacy of the current climate risk disclosures, U.S. regulators should build on their global counterparts' models and issue rules for climate risk disclosures. They should monitor the rules for effectiveness. Such action by regulators would be directly responsive to market demand for enhanced climate disclosure.

Investors are increasingly demanding more comprehensive and useful climate-related information. The Climate Action 100+ initiative—where more than 450 investors representing more than $40 trillion in assets engage the largest carbon intensive companies—identifies TCFD-based climate risk disclosure as a foundational principle (CA100, 2019). Recent proxy seasons have continued to demonstrate strong investor interest in climate change. Investors and investor groups have called on companies to voluntarily adopt frameworks and standards, proffered by organizations such as the TCFD and SASB, to improve the quality of climate-related disclosure (Fink, 2020; Taraporevala, 2020). Additionally, they have called on the G20 financial regulators to incorporate TCFD into their standards (IAFP, 2019). The Investor-as-Owner Subcommittee of the SEC Investor Advisory Committee recommended in May 2020 that the reporting requirements of issuers be updated to cover material, decision-useful ESG factors (SEC, 2020).

Currently, although many large companies voluntarily disclose their climate-related risks, disclosure generally exhibits inconsistent quality, lacks comparability, and varies by industry (TCFD, 2019b). In its 2019 status report, the TCFD found that, on average, the banking industry was a relative leader in adhering to the TCFD's disclosure recommendations, whereas industries like transportation, agriculture, forestry, food, technology and media, and consumer goods tended to have the lowest rates of disclosure (TCFD, 2019b). This disclosure gap is particularly concerning because financial institutions require effective climate-related disclosures to adequately factor climate risks into their decisions. This imbalance between the climate-related disclosure provided and the information needed for analysis and decision-making underscores the importance of regulatory action to close the gap.

Disclosure of material climate risk is essential, but the existing disclosure regime cannot fill the reporting gaps discussed in this chapter. The primary barrier is the significant ambiguity about when climate change rises to the threshold of materiality, particularly for medium- and long-term risks. Without further clarity on what is material and therefore on what must be disclosed, companies concerned about being disadvantaged by moving sooner than their competitors are unlikely to proactively expand their disclosure. Comparable disclosure cannot develop without clear rules about what metrics companies should consider.

Investors need robust climate risk disclosure to fulfill their fiduciary obligations. Fiduciaries and investors, surveys show, consider ESG risks, including climate risk, as a part of their fiduciary duties (Comtois, 2019), and believe that ignoring ESG factors could lead to "material risk" (Idzelis, 2019). From a global perspective, the IOSCO recommended in 2019 that securities regulators ensure that institutional investors, consistent with their fiduciary duties, incorporate ESG issues into investment analysis, strategies and governance, and consider the material ESG risks of the companies in which they invest (IOSCO, 2019). As discussed in Chapter 8, that is not possible without comparable, reliable and decision useful information.

Credit rating agencies are starting to factor in climate risks in assessing the creditworthiness of public and private sector organizations and transactions because, among other things, climate change can impact cash flows and borrowers' ability to meet their debt obligations. The continued absence of reliable, relevant, and comparable climate disclosures, both across and within sectors, will hamper credit rating agencies' ability to fully account for the potential impacts of climate risk on creditworthiness.

U.S. regulators are well positioned to facilitate the process of enhancing the availability and quality of decision-useful climate-related information. Existing regulatory guidance largely applies to climate risk, where climate risks are material to a regulated security (SEC, 2010). However, the unique nature of climate risk means that clearer rules are needed to increase the level and improve the quality of disclosure. Absent this clarity, lack of information will continue to impede the efficiency of markets and their ability to accurately price climate risks and opportunities (Krueger, 2015).

Recommendations

In developing and implementing the recommendations below, financial regulators and the entities they oversee should consult with stakeholders, including investors, businesses, global peers, and other market intermediaries to create a U.S. climate disclosure regime. They also should closely coordinate with international bodies and foreign regulators to ensure the U.S. regime is aligned internationally. Because the understanding of climate risk remains at an early stage, any regulatory approach to climate-related disclosure should evolve in line with emerging best practices. Regulators should continually monitor the state of corporate climate disclosures, evolving clarity on the financial impacts of climate change and emerging best practices. This will allow regulators to continually monitor the quality of the information disclosed in a sophisticated manner, and issue supplemental guidance or begin rulemaking where needed to reflect emerging best practice and market needs. A mandatory, standardized disclosure framework for material climate risks, including guidance about what should be disclosed that is closely aligned with developing international consensus, would improve the utility and cost-effectiveness of disclosures.

Financial Market Regulators

Recommendation 7.1: All financial regulators should consider the following principles for effective disclosure, which are mainly derived from principles developed by the Task Force on Climate-related Financial Disclosures, when developing rules on climate risk disclosure, implementing existing rules or guidance, or seeking public comment on actions they should take:

- Disclosures should represent relevant information.
- Disclosures should be specific and complete.
- Disclosures should be clear, balanced, and understandable.
- Disclosures should be consistent over time.
- Disclosures should be comparable among companies within a sector, industry, or portfolio.
- Disclosures should be reliable, verifiable, and objective.
- Disclosures should be based on current consensus science (and updated as the science evolves) and the best available projections regarding climate change impacts.
- Disclosures should be provided on a timely basis.

Recommendation 7.2: Material climate risks must be disclosed under existing law, and climate risk disclosure should cover material risks for various time horizons. To address investor concerns around ambiguity on when climate change rises to the threshold of materiality, financial regulators should clarify the definition of materiality for disclosing medium- and long-term climate risks, including through quantitative and qualitative factors, as appropriate. Financial filings should include disclosure of any material financial risks from climate change in a consistent but non-boilerplate manner, as well as a qualitative description of how firms assess and monitor for potential changes in climate risks that may become material.

Recommendation 7.3: Regulators should consider additional, appropriate avenues for firms to disclose other substantive climate risks that do not pass the materiality threshold over various time horizons outside of their filings. Regulators should consider that a growing number of companies are creating greenhouse gas reduction targets and strategies out to the year 2035 or 2050, and targeted disclosure related to these items may be appropriate to facilitate robust efforts toward this positive trend.

Recommendation 7.4: Recognizing the costs associated with collecting, assessing and disclosing climate risk information, financial regulators should consider whether smaller companies could be provided a longer period of time to provide their initial disclosures, and the specific disclosures required of those companies could be different and less burdensome than those required of larger issuers.

Recommendation 7.5: In light of global advancements in the past 10 years in understanding and disclosing climate risks, regulators should review and update the SEC's 2010 *Guidance* on climate risk disclosure to achieve greater consistency in disclosure to help inform the market. Regulators should also consider rulemaking, where relevant, and ensure implementation of the *Guidance*. Such an update could incorporate advice on:

- Information that is needed from all companies in order to enable financial regulators to assess the systemic risks posed by climate change. Federal financial market regulators should work closely with prudential regulators to develop these rules.

- Industry-specific climate risk information. Rules should build from existing standards that provide industry-specific climate disclosure recommendations, for example, those developed by the TCFD, SASB, CDSB, the Physical Risks of Climate Change (P-ROCC) framework, and the Global Real Estate Sustainability Benchmark (GRESB) standards for real estate and infrastructure. Because these standards are already sophisticated, regulators do not need to create their own standards or metrics from scratch. Regulators should encourage stakeholders to partner with these standard-setting bodies to further develop, standardize, implement, and validate these metrics over time. Regulators should also acknowledge, in any rulemaking, that climate disclosure standards continue to evolve, and it could provide issuers flexibility, where appropriate, to adopt these evolving standards.

- Governance, risk management and scenario planning information that demonstrates how well companies are situated for a clean energy transition. Federal financial market regulators should work closely with prudential regulators to develop these rules. Scenario planning disclosure is discussed in Chapter 6. Regarding governance and risk management disclosure, regulators should consider the TCFD's recommendations and the Committee of Sponsoring Organizations of the Treadway Commission/World Business Council for Sustainable Development (COSO/WBCSD) guidance, applying enterprise risk management to environmental, social and governance-related risks.

Recommendation 7.6: Regulators should require listed companies to disclose Scope 1 and 2 emissions. As reliable transition risk metrics and consistent methodologies for Scope 3 emissions are developed, financial regulators should require their disclosure, to the extent they are material.

Recommendation 7.7: Regarding derivatives, financial regulators should examine the extent to which climate impacts are addressed in disclosures required of the entities they regulate and consider guidance and rulemaking if disclosure improvements are needed. This could include, for example, swap dealers registered with the CFTC, risk management rules that govern risk identification approaches; Quarterly Risk Exposure Reports, and business conduct rules that govern disclosure of material information to counterparties prior to entering into a swap.

Accounting Standards Regulators

Recommendation 7.8: Once climate risk disclosure standards are well advanced, accounting standards regulators should undertake a mapping exercise of the applicability of accounting standards to climate-related disclosure and subsequently issue guidance on disclosure, as appropriate. This would provide U.S. companies greater clarity about how climate risks may be integrated into financial statements.

Recommendation 7.9: The United States should direct the Federal Accounting Standards Advisory Board (FASAB) to study and pilot the development of climate-related federal accounting standards, disclosure procedures and practices for U.S. government departments, agencies and administrative units.

Municipal Securities Regulators

Recommendation 7.10: Municipal securities regulators should provide improved tools on the EMMA website to search for climate-related disclosure in municipal bond filings, similar to that provided for publicly traded companies, to allow better assessments of potential climate risk exposure in such assets and how they are being addressed.

Recommendation 7.11: Municipal securities regulators and the federal financial market regulator overseeing them should examine the quality of climate-related disclosures in municipal bonds' official statements and continuing disclosures, and whether the disclosure provided is adequate for market participants to assess any underlying climate risk exposure. If disclosure is found to be deficient, they should issue a public statement calling on key stakeholders to improve disclosure, including municipalities, municipal advisers, and banks.

Recommendation 7.12: Municipal securities regulators and federal financial market and prudential regulators should study how risks facing municipalities differ from—and could in some cases be more impactful than—risks facing issuers and explore options to enhance disclosure on these issues. Some municipalities already disclose information, as part of their bond issuances, about floods, storms, dam safety, droughts, wildfires, sea level rise, and risk mitigation efforts, and further study could demonstrate that such disclosure should be enhanced.

Chapter 8

A Closer Look at Financing the Net-Zero Transition

This chapter examines how financial regulators can accelerate the transition to a net-zero, climate-resilient economy. It focuses on the structural changes and market innovations that can expand capital flows to sustainable finance solutions, which are a key component of managing physical and transition risk in the U.S. financial system. As Chapter 1 notes, it is essential that the United States establish a price on carbon. This is the single most important step to manage climate risk.

Financial products have a variety of risks, and this report has articulated the financial implications of climate risk in detail. Financial innovation is required to further develop the tools and resulting products that can efficiently manage climate risk and facilitate the allocation of capital to an economy-wide, net-zero transition. The transition to a resilient, net-zero emissions future is the linchpin in managing long-term climate risk to the U.S. economy and households. Doing so requires embedding climate risk within the risk management frameworks of financial institutions, expanding climate risk data, building expertise in managing climate risks, leveraging scenario analysis, and improving disclosure.

This chapter highlights a selection of the many measures that regulators, financial institutions, and market participants can adopt to catalyze climate-related investment. Once carbon pricing is adopted, these measures will be equally if not more important in facilitating orderly shifts in investment decisions. While some financial products are already available to assist market participants interested in investing in the transition, this chapter focuses on the scale of investment needed and the gaps where further institutional effort is necessary to facilitate the development of climate-related financial products and services.

Estimating the Scale of Investment Needed

Reducing emissions and limiting warming and adapting to the changing climate will require significant public and private investment. Key objectives include deploying low or zero carbon technologies, accelerating innovation in carbon capture, utilization and storage technologies (CCUS), sequestering emissions through natural climate solutions, and developing infrastructure and technologies needed to adapt to physical risks.

Investment needs are broadly estimated to be in the trillions of dollars. One estimate comes from the International Renewable Energy Agency (IRENA), which charts an ambitious yet technically and economically feasible path for limiting warming to "well below" 2 degrees Celsius, in line with the Paris Agreement. IRENA estimates that $110 trillion of cumulative worldwide investment in the energy sector will be needed leading up to 2050 (IRENA, 2019). That equates to roughly 2 percent of average global gross domestic product (GDP) per year over the period. Of the $110 trillion, $95 trillion is already required under the reference case scenario of current plans and policies but would need to be redirected from investments in high-carbon to low-carbon activities. An additional $15 trillion is necessary to further reduce emissions. This transformation is estimated to boost total global GDP by 2.5 percent, or 5.3 percent when considering the avoided climate-related damages relative to the reference case (maintenance of current plans and policies). The transition would result in $11.8 trillion in stranded assets by 2050, but delaying action would nearly double total stranded assets to $19.5 trillion by 2050. However, the cumulative benefit in terms of avoided climate-related and air pollution damages ranges from $50 trillion to $142 trillion, and reducing fossil fuel subsidies would generate further savings of $15 trillion by 2050, relative to the reference case.

Decarbonizing the U.S. power grid over the next 10 to 20 years has been estimated to cost upward of $4.5 trillion (Wood MacKenzie, 2019). This and other estimates generally focus on the direct costs of transitioning domestic energy infrastructure, while there are additional costs to transition transportation, agriculture, and industry. However, these cost estimates reflect significant economic opportunity, and it is useful to consider them alongside the counterfactual costs of business-as-usual, as well as the co-benefits that arise from technological innovation, new categories of labor and expanded employment, and the avoided costs associated with the improved resilience of infrastructure.

Mobilizing the trillions of dollars necessary to finance the technologies and activities that support the net-zero transition will require tapping into vast pools of capital. In a financial environment characterized by ultra-low interest rates, institutional investors are seeking higher returns, as long as investments meet their preferred risk-return profile and investment horizons. Despite inadequate incentives to reduce emissions and various structural barriers, U.S. investors are already starting to position themselves for the inevitable transition.

Barriers to Sustainable Investing

Misperceptions about Risk-Return

Multiple barriers may be holding back U.S.-based institutional investors. One involves a common, long-held misperception among investors that sustainable or environmental, social and governance (ESG) investments necessarily have lower returns relative to traditional investment strategies. This is based on the historical view that ESG investing is a values-driven activity, and that ESG data and principles may be incongruent with a fiduciary duty to seek the highest returns. This perspective underlies historical practices like omitting certain companies or sectors via ESG screens. These misperceptions ignore the evolution of a wide range of financial ESG factors and strategies, as well as the proposition that impact investing may yield additional returns. This report in general, particularly Chapter 5, details the variety of ways climate risk management could drive improved risk-return.

The nature of financial markets perpetuates these misperceptions. Asset owners and managers set investment strategies and evaluate returns based on benchmarks and strategic asset-allocation targets. Managed funds often raise capital based on explicit terms including investment theses and lock-up periods ranging from months to years. Return targets tend to be based on historical returns or on capital market forecasts premised on economic growth and other factors. This practice drives a strong status quo bias that undermines a more complete evaluation of what the future may bring, including future opportunities associated with managing climate risk. Without a historical track record or clear empirical justification, it is often difficult for traditional investors to integrate sustainable investments into their portfolios. Ultimately, empirical evidence does not support these collective barriers characterizing sustainable investments as inferior. Studies analyzing financial performance across a large sample of ESG approaches show that making investment decisions using ESG factors does not hurt investment performance across the sample, and, in some cases, it enhances risk-adjusted returns (Friede et al., 2015; Morgan Stanley, 2015a; Morgan Stanley, 2015b; Clark et al., 2015; Khan, et al., 2016).

Insufficient Investment Opportunities

A second barrier to sustainable investment is the shortage of climate-related investment opportunities relative to investor demand. Demand for sustainable investments is large and growing. Coalitions of asset owners, asset managers, and other financial institutions are expressing interest and support for sustainable investment. For example, the U.N. Principles for Responsible Investment (PRI) includes more than 3,000 investor signatories with more than $100 trillion in assets under management. However, expressions of support have not translated into the necessary capital flows.

In addition, a growing number of asset owners, including endowments and pension funds, are committing to transitioning their investment portfolios to net-zero emissions by 2050—a goal consistent with a maximum temperature rise of 1.5 degrees Celsius above pre-industrial temperatures and in alignment with the Paris Agreement. The Paris Agreement has increasingly motivated U.S. and global companies and investors to voluntarily commit to reducing their carbon footprints, and some firms have pledged to achieve net-zero or net-negative emissions. Recently, Harvard University and Stanford University, which manage two of the five largest university endowments globally, committed to net-zero portfolios (HMC, 2020; Stanford, 2020).

The market for products widely considered to be "green" or "sustainable" is rapidly expanding but remains small relative to institutional investors' needs. A growing number of opportunities are focused on integrating climate risk and investing in the transition, but many of the opportunities have been within private markets, including venture capital, private equity and infrastructure. Public equity and debt markets are significantly larger and more liquid but offer far fewer sustainable investment opportunities.

With respect to debt, even though global green bond issuance hit a record $255 billion in 2019, it was not nearly enough to satisfy investor demand, particularly once emerging market risk and other constraints were considered (Chestney, 2020). Similarly, investors have few options for sustainable U.S. corporate debt exchange-traded funds (ETFs). Among the largest global asset management firms, only a few U.S.-domiciled ETFs with any measure of sustainability focus are currently available. A variety of factors are driving these limitations.

The lack of sufficient scale is even more clear in equity markets, as is the gulf between Europe and the United States. In Europe and elsewhere, investors are shifting increasing portions of their portfolios to "green" or "sustainable" assets. For example, as of March 2020, total sustainable European fund (open-end funds and ETFs) assets reached a record of more than $680 billion (Morningstar, 2020). By comparison, sustainable U.S. fund (open-end funds and ETFs) assets totaled nearly $120 billion (Morningstar, 2020). In the first quarter of 2020, $45.6 billion globally flowed into ESG funds, with 72.4% of ESG inflows in Europe relative to 22.8% in the United States, and this occurred in the context of an outflow of $384.7 billion for the overall fund universe (Morningstar). These trends suggest that U.S. demand for these products may be weaker relative to European demand for a variety of reasons, including the lack of proper incentives.

Concerns About "Greenwashing"

A third barrier holding back sustainable investment may be concerns about potential "greenwashing." Some investors lack confidence that "sustainable" or ESG-labeled products are as green as they claim to be. These concerns form the partial basis for a current SEC Request for Comment about the naming of funds and investment companies (SEC, 2020). The absence of widely accepted, consistent definitions and standards for climate risk data in

general, and sustainable investing in particular, may be hindering market development. It is difficult for investors to understand what labels such as "ESG," "sustainable," "green," "low-carbon," or "net-zero" actually mean and to compare products that carry the same label.

Today, financial products may be identified as sustainable or green, based on the proprietary research of the provider. Investors looking for consistency in labeling can rely on private certification entities, but with potential implications for cost and comparability. Private certifications are limited to a comparatively narrow range of sectors and asset classes. Their advantage is that they likely incorporate emerging intelligence and expertise on climate risks, uncertainties, and opportunities. Their disadvantage is that comparability may be difficult.

Credible data is the foundation of any financial product's sustainability credentials. It can be attained from emerging public source and proprietary data providers, as well as from corporate disclosure and reporting. The goal is consistent and comparable information. A lack of available climate risk data is hindering the development of sustainable investment products, including derivatives based on ESG or sustainable assets. For example, certain carbon indices are designed to screen for companies based on their carbon intensities or environmental performance. But to build datasets like that, clearly demarcated methodologies and definitions are needed to ensure the integrity of financial products such as over-the-counter (OTC) and listed derivatives with ESG and, more specifically, carbon-related underliers. Clear definitions and methodologies are also necessary for central counterparties to adequately assess and manage risks associated with listed ESG contracts.

Policy Uncertainty

One of the most critical factors holding back sustainable investment is policy uncertainty. The lack of carbon pricing and uncertainty about climate policy more generally create enormous financial risk and make long-term investments in energy, infrastructure and other sectors difficult to effectively value. This difficulty reduces the flow of capital to renewable energy and other existing low-carbon technologies, and to new technological innovations needed across nearly every sector. Technological innovation, from initial research through pre-pilot, pilot and initial commercialization, is an area of particular market failure, given the long time horizon to commercialization, the capital intensity of many sectors, and the risk aversion of market participants.

While the absence of climate policies impedes sustainable investment, so too do various existing policies. One example is regulation of financial products that U.S. companies may offer to their employees through retirement plans. The Employee Retirement Income Security Act of 1974 (ERISA) and the rules adopted under it by the U.S. Department of Labor (DOL) govern the management of retirement and pension plans. ERISA articulates fiduciary responsibilities that companies must follow in retirement plan offerings. Elements of this regulation may be chilling the offering of sustainable products in U.S. retirement plans.

Guidance issued by the DOL in 2018 and recently proposed amendments to ERISA rules limit how managers of ERISA assets may consider ESG benefits (DOL, 2018; DOL, 2020). Because of misperceptions about risk-return, ERISA plan sponsors and managers also may believe they could risk violating their fiduciary duties if they integrate sustainability factors into their investment approach.

Catalyzing Structural Change and Market Innovation

Addressing barriers and building an ecosystem that supports sustainable finance will require structural shifts. The ultimate goal is that all investment products and services internalize climate risks and opportunities in a manner that drives dynamic competition and mitigates GHG emissions. Effectively pricing carbon is the best way to recognize the inherent risk-return profile of sustainable investments and would significantly expand the market for them. However, gaps remain, and policymakers have an important role to play in reducing barriers and harnessing the innovative capacity of markets.

Fiscal Policy

Beyond carbon pricing, a wide range of complementary policies can mitigate climate risk and advance the transition to a net-zero emissions future. The U.S. government's fiscal authority—its capacity to spend, borrow, and structure the tax code—can significantly increase the scale of investment in sustainable projects. To be sure, trillions of dollars are needed for the transition, and there are limits to how much the government can do on its own. Additionally, constant changes in the direction of fiscal policy can sustain policy uncertainty. Fiscal policy nevertheless can advance the transition in many ways. Project standards can be designed to minimize "greenwashing," for example. Fiscal policy can support the many co-benefits of the transition, including job creation and the promotion of equity for historically marginalized communities. Additionally, it can drive continued innovation by funding basic scientific research and the deployment of mature technologies.

Fiscal policy includes economic stimulus, disaster relief, and infrastructure, all of which have implications for climate risk. The direction of public investment could increase or decrease climate risk across the financial system. The ongoing response to the COVID-19 global economic crisis has included urgently needed economic stimulus. Future spending offers possibilities for reducing the structural barriers holding back the transition to a net-zero emissions future, while simultaneously supporting the economy. Policymakers' ambition should be to enhance the economy's long-term potential, including by managing climate risk, not to maintain the status quo.

Catalyzing Private Capital

Government spending can be structured to more directly address market failures and structural barriers that impede private sector capital flows. These efforts can harness the power and innovation of the financial system to efficiently drive capital toward the net-zero transition. These programs can increase total investment by leveraging private sector dollars alongside public sector dollars. These efforts can help expand the scale of both investor demand and the supply of quality investment opportunities, improve risk-return by stimulating the integration and pricing of climate risk, and aid in definition standardization to alleviate "greenwashing" concerns.

Several successful government programs focus on de-risking certain investments and attracting private capital—effectively expanding the universe of investable green assets. The U.S. Department of Energy (DOE), U.S. Department of Agriculture (USDA), and U.S. Department of Transportation (DOT) have the authority to encourage clean energy and resilience through the loans and loan guarantees they deploy to a range of large-scale infrastructure projects. As of year-end 2019, the DOE Loan Programs Office (LPO) had $44 billion in available loan and loan guarantee authority to support advanced vehicle manufacturing; advanced nuclear; advanced fossil energy (for example, CCUS); renewable energy and energy efficiency; and tribally-owned energy projects (DOE, 2020). Entities such as the Advanced Research Projects Agency-Energy (ARPA-E) provide capital and support to advance innovations that are still too nascent for private sector investment. ARPA-E funding typically averages $500,000 to $10 million. It has provided $2.3 billion since 2009 to 850 projects, many of which led to patents, new companies, or partnerships with other government agencies; 20 percent of the projects went on to raise $3.2 billion in private sector funding (ARPA-E, 2020). These credit enhancements and co-investments attract private sector funds.

Green banks at the state and municipal level have directly addressed a range of barriers and opportunities. Green banks can mitigate barriers of scale by aggregating small transactions and supporting the development of new products. They can foster investor trust by participating in classification guidance and leading the initial development of new markets. They can also help address concerns about financial returns by de-risking investments and familiarizing investors with new markets. Ultimately, many of these programs are focused on attracting private sector capital to increase total funding.

For example, the New York Green Bank (NYGB) is a state-sponsored specialized financial entity that collaborates with the private sector to accelerate and expand sustainable investment. NYGB invests with the goal of unlocking significantly more private capital. Examples include warehousing and aggregation facilities, term loans, credit enhancements, and construction finance. As of the first quarter of 2020, NYGB had invested nearly $960 million in energy efficiency, solar, sustainable transportation, and fuel cell projects.

NYGB is targeting a ratio of total project investment to NYGB funds of 8-to-1. Its goal is to eventually generate $8 billion in investment from its $1 billion of capital. So far, the bank has mobilized $2.6 billion (NYGB, 2020).

Existing authorities could be leveraged and expanded into a more unified program, perhaps under a federal umbrella, that could coordinate a wide range of government programs and provide an increase in institutional capital to maximize their impact. Potential tools could include those that are already actively used, such as lending and credit enhancements. The federal umbrella could also facilitate the initial capitalization of state and local green banks and other state climate initiatives.

Supportive Regulatory Policy

Regulators have long supported innovation in the markets they oversee. They could do the same for sustainable investments. Regulation, for example around permitting and federal leasing, can stimulate capital flows. Financial regulators have sought to facilitate financial technology (fintech) innovation and at the same time tried to ensure their policies keep pace with the ever-changing financial services industry. By the same token, fintech innovators need a detailed understanding of regulation to pursue their work successfully.

Financial regulators support innovation through regulatory labs or sandboxes. A lab serves as forum for firms to engage with regulators. They help regulators adapt their regulatory frameworks to innovation and help market participants navigate regulation. Sandboxes go further by creating a formal structure for innovators to develop and test new products and services, with regulatory oversight and support. Labs and sandboxes can also drive innovation via accelerators, grants and competitions providing awards in specific areas. Labs and sandboxes established by domestic and foreign regulators currently focus on fintech innovation in general. For example, the CFTC established LabCFTC with the aim of—"facilitating market-enhancing FinTech innovation, informing policy, and ensuring that the agency has the regulatory and technological tools and understanding to keep pace with changing markets" (CFTC, 2019).

A similar approach could be used to drive market innovation for climate-related financial products. Climate-related financial innovation, including climate data platforms and climate fintech solutions, is crucial for managing climate risk and driving the transition to a net-zero emissions future. A climate finance lab or sandbox could enhance emerging innovations relating to climate risk data and analysis and facilitate the development of innovative financial products.

In addition, labs and sandboxes, as well as catalytic funding programs, can facilitate access to data and expertise. By improving the availability and consistency of data, government programs can reduce private sector risk aversion to creating new or modified financial products and services (Keenan, 2019). Improved data integration and access would encourage the development of new climate-related technologies and products, particularly the emerging efforts to use nature-based solutions for physical climate resilience and

adaptation investments. Some programs to integrate and communicate data already exist, such as the U.S. Department of Energy's Energy Investment Center, which was established to share the technical expertise of the Department's National Laboratories with investors.

Finally, the clarification of existing rules could help unlock sustainable investment. As noted, regulatory concerns may discourage ERISA plan sponsors and managers from integrating climate-related factors into their investment approach. Similar concerns arise in other situations where there is fiduciary duty. They include the potential misperception of risk-return, worry about violating unclear standards (including those caused by conflicts or changes in regulatory guidance), and potential liability for the underperformance of investments being attributed to their sustainability features.

Clarification is necessary to confirm the appropriateness of making investment decisions using climate-related factors—and more broadly, ESG factors that impact-risk return. Because climate-related factors may affect financial performance, they should be considered by fiduciaries to the same extent as "traditional" financial factors—such as valuation, profitability ratios, and management strength. Regulatory efforts must not discourage the consideration of these factors, and instead should encourage their consideration. Climate risk and opportunities, as well as broader sustainability and ESG factors, need to be considered as part of the analysis of financial fundamentals and the normal investment process.

Innovation in Derivatives Markets

For more than 25 years, derivatives have been used to hedge climate-related risks. The need for new products likely will grow. Various OTC and exchange-traded climate-related derivatives currently are used by agricultural, energy and metals market participants, as well as financial entities. These instruments include traditional weather derivatives, electricity futures, and relatively new instruments, such as ESG futures and carbon derivatives based on equity indices. Broadly speaking, derivatives can address climate-related risk through adjusting existing instruments and by providing new instruments.

To advance the market for climate-related derivatives, regulators should consider appropriate and targeted exemptions from their rules when needed to facilitate coordination with other regulators and promote market development. For example, the CFTC classified environmental commodities as non-financial commodities, thus allowing them to be purchased and sold pursuant to excluded spot and forward contracts. This paved the way for primary regulation by the agencies designing the underlying market—the Environmental Protection Agency for Renewable Fuel Standards (RFS) markets and state agencies for existing Renewable Portfolio Standards (RPS) and carbon markets.

The CFTC provided guidance to these primary regulators based on its experience as a market regulator. For example, in its *Report on the Oversight of Existing and Prospective Carbon Markets*, the CFTC encouraged broad and open market participation and emphasized

that "rules and trading systems should be designed to encourage market liquidity, facilitate price discovery and allow those directly and indirectly impacted by the regulation of carbon emissions to efficiently hedge associated risks" (CFTC, 2011, p. 50). Appropriate oversight of primary and secondary markets could be revisited "if or when Congress considers Federal market-based options for reducing greenhouse gas (GHG) emissions" (CFTC, 2011, p. 52).

Reducing Exposure to Climate-Related Risks within Existing Instruments

Businesses and consumers are increasingly focused on the environmental impact of the commodities they produce and consume. As a result, businesses often desire greater oversight and understanding of their supply chains to ensure that the commodities meet certain sustainability definitions and standards. This trend will likely impact not only commodity spot markets, but also the corresponding derivative markets.

As a result, commodity derivatives exchanges may seek to incorporate sustainability- and climate-related elements into existing contracts. As environmental standards evolve, futures contracts will need to be modified to replicate changes to the physical market. Consider, for example, the recent transition from high-sulfur fuel oil (HSFO) to low-sulfur fuel oil (LSFO) to comply with the terms of the United Nation's International Maritime Organizations 2020 international agreement. Or the metals industry, where the London Bullion Market Association (LMBA) introduced a Responsible Sourcing program for precious metals that aims to protect the integrity of the global supply chain for the wholesale precious metals markets. In conjunction with these physical market changes, all COMEX physically delivered gold futures contracts were modified to ensure compliance with LBMA Responsible Gold Guidance, which formalizes and consolidates standards of due diligence among all LBMA Good Delivery Refiners. Agricultural suppliers are increasingly asked to deliver "greener" commodities with specified environmental traits, such as low-methane rice, the standards could become incorporated into existing product specifications.

However, there are various challenges to modifying these exchange-listed contracts. Some market participants may be reluctant to support sustainability specifications because of a lack of verifiable climate-related standards and concerns that sustainability specifications may reduce the liquidity of the product (World Federation of Exchanges, 2019). Commodity exchanges should work closely with the industry and the CFTC to anticipate future product changes influenced by climate risk so that contracts related to them can be traded effectively. Private sector players can also help establish trust and transparency for climate-related standards and guidelines as existing products are modified to incorporate sustainability elements. This is like the role price reporting agencies currently play in some commodity markets and can help advance price transparency in derivatives markets.

Modifications to existing products are not limited to derivatives traded on commodity derivative exchanges. More recently, some OTC swap contracts have been modified to embed new sustainability incentive mechanisms. Appearing first in an OTC interest

swap in August 2019, and then in October 2019 in a foreign exchange forward swaps, this mechanism consists of reducing one counterparty's payment in the event it achieves some pre-agreed sustainability performance target. If expanded across derivatives, this mechanism could provide market participants with a financial incentive for improved environmental performance.

Providing New Derivatives Products to Hedge Climate-Related Risks

To serve the long-term need for price discovery and risk mitigation, the derivatives industry must provide new, innovative products focused on climate risk. However, there is no comprehensive and comparable set of metrics for climate-related risks, and the ability to accurately quantify climate risks is critically important for financial functions ranging from assessing lending risk, to pricing derivatives, and, ultimately, to constructing sustainable finance products. Derivatives products can only be developed if climate-related data is transparent, reliable and trusted by market participants. If that happens, new-product innovation would likely span multiple asset classes as data becomes more available.

Weather derivatives, or index insurance, have for decades provided customized solutions to address low risk, high probability weather-related events. To date, most exchange-listed weather futures and options are based on weather indexes that aggregate both catastrophic and non-catastrophic data. While these products can help manage localized exposure to weather-related risk, they do not address the broader impact of climate risk. It has been very challenging to develop liquidity in weather derivatives because liquidity providers have no associated risk layoff. Since exchange-traded weather derivatives do not meet reporting thresholds, commodity exchanges have not reported position data for weather derivatives or indexed weather derivatives products to the CFTC.

Extreme weather events, shifting demand patterns, and new technology for renewable power generation, will require the continued development of new products, data, and related technology to improve the ability of electricity market participants to measure and manage their risk. Electricity prices can be extremely volatile, posing challenges for smaller market participants, who often offer renewable energy. Volatility is greater in the intra-day, and short-dated markets where there are few instruments to mitigate risk. Greater volatility results in higher prices for end-use customers. Also, the inability to effectively hedge makes it more difficult for renewable generation to receive funding. Typically, renewable energy providers' sell long-term Purchase Power Agreements (approximately for 10 years), but do not often hedge their operational capacity even one day in advance. Hedging solutions currently available to smaller market participants are prohibitively expensive and lack the detail necessary to provide effective risk management. Lastly, as an increasingly large portion of power generation derives from renewable sources, new futures contracts could be developed to manage risks around wind and solar power generation, as well as transmission and storage, including via managing intermittent generation, congestion risk, and Renewable Energy Certificates markets.

In addition, as demand increases for financial products to manage climate risk, derivatives exchanges likely will seek to develop products where investor interest is high. In 2019, $20.6 billion flowed into ESG funds, four times more than during the previous period (Hale, 2020). ESG ETF and Index futures have seen increased volumes and open interest. To attract a broader set of market participants, these new ESG-related futures contracts will need to develop deeper liquidity. The successful adoption of these derivatives products also depends on the continued growth of ESG funds and the decline of their costs.

The development of new derivative products focused on measurable climate-related events such as sea level rise, extreme rainfall events, and natural disasters should appeal to a broad set of market participants. Reliable and trustworthy data sources that help measure environmental attributes and characteristics throughout the physical commodity supply chain will be needed to underpin these new derivatives contracts. Private sector companies are finding new ways to collect, process, and transfer decision-useful lifecycle datasets to differentiate their products on the basis of their climate impacts and reveal the market value or risks associated with asset-level environmental attributes.

Innovation in Other Financial Markets

While derivatives are a risk-focused product, a wide range of other innovative financial products also can help isolate and manage risk, including climate risk, and thereby drive capital to sustainable investment opportunities. Broadly, these instruments can be grouped into two categories: (i) new instruments to direct capital to climate-related opportunities; and (ii) increased exposure to climate-related opportunities within existing instruments.

New Instruments to Direct Capital to Climate-Related Opportunities

A wide range of financial products directly provide funding to sustainable or transition projects. These instruments can expand capital flows by leveraging improved data and by increasing investor awareness of the return potential for ESG. These instruments provide capital at the corporate or project level.

Many innovative financial structures aim to increase demand from the deep pools of institutional capital. As we saw above, green bonds are widely used due to their relative simplicity. However, more green bonds are needed. While the green bond label can apply to a variety of debt instruments, most have been based on corporate credit and cash flows. In addition, the cost of issuance and the lack of market rewards for issuing remain barriers to the issuance of green bonds. The green bond market has spurred offshoots, including sustainability bonds and Sustainable Development Goal (SDG) bonds, which cover a wider range of eligible projects. More recently, transition bonds have been issued to fund projects that reduce carbon emissions, typically along a pathway compatible with the goals of the Paris Agreement.

Financial products can directly deploy investors' capital to green assets. This includes venture capital, private equity and infrastructure investments supporting the development and deployment of climate-related technologies. It also includes traditional insurance products for new technologies such as CCUS.

Securitization allows for tranches of risk, attracting new capital and recycling existing capital to continue private sector sustainable investment. In addition to securitization of green assets, innovation in securitization could help with difficult local stranded asset problems, including how to retire older highly polluting power plants without excessively burdening ratepayers. In a regulated utility securitization, utilities issue bonds that are paid back through a discrete customer charge. Customers benefit because the utility is refinancing the unrecovered value of the plant being retired at a lower cost than if the utility issued stock. Credit agencies generally view the mechanism positively because the utility recovers its investment and generates cash for other purposes. Securitization, by isolating and allocating climate risk to investors willing to accept it, may prove to be critically important for financing the transition.

Increasing Exposure to Climate-Related Opportunities within Existing Instruments

A nascent but growing range of innovative products prices physical and transition risk within existing instruments. Insurance is an example of a sector with significant advances in integrating climate risk. As the availability of data increases, a range of new financial products, including insurance and insurance linked securities (ILS), are being developed to integrate the benefits of adaptation and resilience activities.

Catastrophe bonds are an innovative security that transfers the catastrophic risk of extreme events, including climate-attributed weather events, to the capital markets. Recently, catastrophe bonds have evolved to account for the changing nature of physical risk. In 2015, the quasi-public National Railroad Passenger Corporation (Amtrak) issued $275 million of catastrophe bonds to cover storm surge, wind damage and earthquakes. It was one of several catastrophe bonds issued after Superstorm Sandy struck in 2012, causing $1 billion of damage to Amtrak tunnels. In the future, the pricing of catastrophe bonds could potentially account for resilience and climate adaptation that might reduce physical risks.

Sustainability-linked loans, revolving credit facilities, letters of credit, and guarantees are emerging which adjust their interest rate to correlate with performance toward achieving sustainability targets. There are new insurance products whose pricing and underwriting reflect the potentially stronger cash flows and valuations of "green" buildings (CDI and UC Berkeley CLEE, 2018). Nature-based solutions can provide unique value. They include property insurance that can take into account the benefits of ecological forestry for reducing the risk of severe wildfires or the benefits of coral reefs, mangroves or salt marshes for reducing the risk of coastal flooding (The Nature Conservancy, 2019).

Recommendations

Effective and well-functioning markets should allocate capital efficiently to net-zero emissions investments, spur innovation, and create and preserve quality jobs in a growing net-zero economy. These recommendations seek to meet these goals by improving the functioning of markets by reducing structural barriers and catalyzing private sector innovation. In undertaking these efforts, consideration should be paid to the distributional and equity impacts on low-to-moderate income households and marginalized communities. In addition, efforts should aim to facilitate an orderly transition, where possible, avoiding adding financial strain on already stressed sectors, including agricultural producers and commercial and industrial companies, among others.

Recommendation 8.1: The United States should consider integration of climate risk into fiscal policy, particularly for economic stimulus activities covering infrastructure, disaster relief, or other federal rebuilding. Current and ongoing fiscal policy decisions have implications for climate risk across the financial system.

Recommendation 8.2: The United States should consolidate and expand government efforts, including loan authorities and co-investment programs, that are focused on addressing market failures by catalyzing private sector climate-related investment. This effort could centralize existing clean energy and climate resilience loan authorities and co-investment programs into a coordinated federal umbrella.

Recommendation 8.3: Financial regulators should establish climate finance labs or regulatory sandboxes to enhance the development of innovative climate risk tools as well as financial products and services that directly integrate climate risk into new or existing instruments.

Recommendation 8.4: The United States and financial regulators should review relevant laws, regulations and codes and provide any necessary clarity to confirm the appropriateness of making investment decisions using climate-related factors in retirement and pension plans covered by ERISA, as well as non-ERISA managed situations where there is fiduciary duty. This should clarify that climate-related factors—as well as ESG factors that impact risk-return more broadly—may be considered to the same extent as "traditional" financial factors, without creating additional burdens.

Recommendation 8.5: The CFTC should pursue the following activities to further catalyze climate finance market development:

- Survey market participants about their use of climate-related derivatives, the adequacy of product availability and market infrastructure, and the availability of data to incorporate climate impacts into existing and new instruments.
- Consider appropriate and targeted exemptions where needed to help facilitate coordination with other regulators and promote market development.
- Support the study and adoption of alternative execution methods, such as block trading, auction style markets, or incentive programs, to attract liquidity providers to make climate-related markets.
- Coordinate with other regulators to support the development of a robust ecosystem of climate-related risk management products.

Conclusion

As this report was being finalized, governments around the world were working assiduously to contain the spread of COVID-19. Along with other major economies, the U.S. economy was suffering from simultaneous demand and supply shocks, the result of the synchronized shutdown of many parts of the economy. Unemployment had surged to post-Depression highs, and the economy was contracting at a record rate. Many households and businesses were suffering from falling income and wealth, as well as deteriorating creditworthiness. Stress in financial markets subsided only after the Federal Reserve launched interventions of unprecedented scale and scope, and Congress approved historically large fiscal measures to assist businesses and households. While the "great shutdown" to contain the virus led to a significant drop in global greenhouse gas emissions, the decline was temporary and not expected to fundamentally change the overall course of global emissions.

The pandemic is relevant to this report because its legacy will likely be prolonged fiscal deterioration, stressed business balance sheets, and depleted household wealth. In this context of heightened financial fragility, managing climate-related risk becomes even more important and urgent.

This report has argued that the physical impacts of climate change are already affecting the United States, and over time, will likely touch virtually every sector and region of the country. Depending on the evolution of policy, technology, and consumer preferences, the transition to net-zero emissions may also impact many segments of the economy. Both physical and transition risks could give rise to systemic and sub-systemic financial shocks, potentially causing unprecedented disruption in the proper functioning of financial markets and institutions. Sub-systemic shocks to particular sectors or regions could reduce access to financial services by marginalized communities and people already underserved by the financial system. Climate impacts may also magnify or exacerbate existing, non-climate-related vulnerabilities in the financial system, with potentially serious consequences for market stability.

A financial system that is better able to measure and manage these risks will be better positioned to absorb and recover from climate-related shocks, as well as to help investors and entrepreneurs seize opportunities that arise from the transition to net-zero emissions. That will be especially significant in the post-COVID period, when the weakened economy and financial system will be especially vulnerable to any additional disruption. Given the uncertain timing of physical and transition risks, it is imperative that this process begin now.

As this report has mentioned repeatedly, policies essential to decisively address climate change lie beyond the purview of financial regulators. Those policies include, first and foremost, effective mechanisms to price carbon appropriately. Financial regulators and other market participants can insistently point to the need to "get incentives right," and they can warn about the consequences of failing to act. But, ultimately, these critical policies must come from Congress, coupled with an international framework that can facilitate synchronized reductions in greenhouse gas emissions across countries.

However, that does not mean financial regulators have little to do while an adequate carbon-pricing regime emerges. Quite the contrary. This report has argued that financial regulators should actively promote, and in some cases require, better understanding, quantification, disclosure, and management of climate-related risks by financial institutions, large dealers, investors, asset owners and managers, and other market participants. They should also work to preserve the proper functioning of markets in the face of low-probability but high-impact risks. As this report has noted, regulators already enjoy wide latitude, on the basis of existing authorities, to advance these objectives.

To be sure, the road ahead will not be straight. The evolution of climate change and its impacts is highly uncertain. Also, as these pages have described, climate-related data, models, and scenario planning, remain in an incipient stage. Therefore, the process of strengthening climate risk management will be inherently experimental and demand constant learning and innovation. Persistent evaluation, consultation, and course-correction will be par for the course.

While this report has been addressed to financial regulators, financial market participants also have a critical role. In this context, financial regulators can help by encouraging and facilitating innovation in financial firms' risk management. This includes innovations in scenario planning, improvements in environmental, social, and governance (ESG) data, and better methodologies for measuring climate-related financial risk.

At the same time, regulators can help promote the role of financial markets as providers of solutions to climate-related problems. A good example is the derivatives market, which thanks in part to regulatory changes, has evolved from a magnifier of financial shockwaves during the 2008 Global Financial Crisis to a source of risk-management instruments that can help preserve financial stability. Innovations in the derivatives market may also help market participants manage climate-related risks and maximize climate-related opportunities in the future. Importantly, financial innovation will result not only in products for managing risk, but also for promoting the flow of capital toward net-zero-emission, climate-resilient technologies and investments.

A theme that has run through this report is that the United States is not alone in confronting this challenge. Financial regulators around the world, including from many of the leading economies; multilateral organizations; and groups of investors and major financial institutions have joined this mission. Together, they are generating a plethora of initiatives and tools to safeguard financial stability in the face of climate risk. However, the United States remains, at best, a reluctant participant in these efforts, and in some cases, it is absent. Without the full involvement of the largest economy and home to the world's largest capital markets, international efforts will surely fall short. As this report has argued, the United States should fully participate in these forums and help lead the way.

Finally, in a report such as this, it is important to recall the ultimate objective. Financial stability is not an end it itself—it is a means to protect the assets of millions of Americans and to ensure that the financial system continues to support their goals and aspirations through an efficient and sustainable allocation of capital. In a world confronting climate change, it is imperative that the financial system continue to serve this purpose and, where possible, to advance the solutions needed to meet the climate challenge.

List of Recommendations

Chapter 1

Recommendation 1: The United States should establish a price on carbon. It must be fair, economy-wide, and effective in reducing emissions consistent with the Paris Agreement. This is the single most important step to manage climate risk and drive the appropriate allocation of capital.

Chapter 4

Market participants and the regulatory community, in the United States and abroad, are in the early stages of understanding and experimenting with how best to monitor and manage climate risk. Given the considerable complexities and data challenges involved, regulators and market participants should adopt pragmatic approaches that stress continuous monitoring, experimentation, and learning. Regulatory approaches in this area are evolving and should remain open to refinement, especially as the understanding of climate risk continues to advance and new data and tools become available.

At the same time, regulators should establish a clear framework with appropriate milestones. This is what financial regulators are already doing in some jurisdictions and is consistent with recommendations of financial regulatory bodies (Bank of England, 2019; Bank for International Settlements, 2020; NGFS, 2020). As explained above, in general, regulators have sufficient authority to start tackling climate risk immediately. The following recommendations provide, in our view, a good starting point.

Systemic Risk Oversight

Recommendation 4.1: All relevant federal financial regulatory agencies should incorporate climate-related risks into their mandates and develop a strategy for integrating these risks in their work, including into their existing monitoring and oversight functions. Regulators should further develop internal capacity on climate-related risk measurement and management, including through their strategic planning, organizational structure, and additional resourcing.

Recommendation 4.2: The Financial Stability Oversight Council (FSOC), of which the Commodity Futures Trading Commission (CFTC) is a voting member, should undertake the following:

- As part of its mandate to monitor and identify emerging threats to financial stability, incorporate climate-related financial risks into its existing oversight function, including its annual reports and other reporting to Congress;
- Encourage and coordinate, across the Council's member agencies, the sharing of best practices concerning the monitoring and management of climate-related risks, the building of relevant institutional capacity, the integration of climate-related risks into the risk monitoring function of the agencies and into financial supervision and regulatory frameworks, and the potential for second-order impacts, such as the migration of financial activity from one part of the financial system to another; and
- Task the Office of Financial Research with developing a long-term program of research on climate-related risks to the financial system, paying close to the potential interconnectivity and spillovers of climate-related risks across the financial system; monitoring relevant developments; and developing tools that regulators can use for the monitoring and management of climate-related risks.

Recommendation 4.3: Research arms of federal financial regulators should undertake research on the financial implications of climate-related risks. This research program should cover the potential for and implications of climate-related "sub-systemic" shocks to financial markets and institutions in particular sectors and regions of the United States, including, for example, agricultural and community banks and financial institutions serving low-to-moderate income or marginalized communities. Research should also include the impact of climate risk on financial system assets and liabilities, including by sensitivity of specific sectors to climate change, geographic location, and tenor. In doing so, regulators should identify data gaps and approaches to address these shortcomings. Regulators should develop assessments of the magnitude of the impact of climate on these assets and liabilities, for example through scenario analysis.

Recommendation 4.4: Relevant federal regulators should assess the exposure and implications of climate-related risks for the portfolios and balance sheets of the government-sponsored enterprises (GSEs) and strongly encourage the GSEs to adopt and implement strategies to monitor and manage those risks.

Recommendation 4.5: The Federal Insurance Office, in collaboration with state insurance regulators, should undertake an assessment of the insurance sector's systemic vulnerability to climate-related impacts and report the findings to the FSOC. FIO should also evaluate the adequacy of state insurance regulators' oversight of climate-related risks.

Recommendation 4.6: Federal financial regulators should actively engage their international counterparts to exchange information and draw lessons on emerging good practice regarding the monitoring and management of climate-related financial risks. U.S. regulators should join, as full members, groups convened for this purpose, including the Central Banks and Supervisors Network for Greening the Financial System (NGFS), the Coalition of Finance Ministers for Climate Action, and the Sustainable Insurance Forum (SIF). The United States should also engage actively to ensure that climate risk is on the agenda of Group of Seven (G7) and Group of Twenty (G20) meetings and bodies, including the Financial Stability Board (FSB) and related committees and working groups. The Federal Reserve already participates in the Basel Committee on Banking Supervision's climate task force, and the Securities and Exchange Commission participates in the International Organization of Securities Commissions' (IOSCO) sustainable finance network.

Risk Management

Recommendation 4.7: Financial supervisors should require bank and nonbank financial firms to address climate-related financial risks through their existing risk management frameworks in a way that is appropriately governed by corporate management. That includes embedding climate risk monitoring and management into the firms' governance frameworks, including by means of clearly defined oversight responsibilities in the board of directors.

Recommendation 4.8: Working closely with financial institutions, regulators should undertake—as well as assist financial institutions to undertake on their own—pilot climate risk stress testing as is being undertaken in other jurisdictions and as recommended by the NGFS. This will enable stakeholders to better understand institutions' exposure to climate-related physical and transition risks, as well as to explore climate-related opportunities. The pilot program should include the testing of balance sheets against a common set of scenarios (elaborated on in Chapter 6 and Recommendation 6.6), covering how financial institutions might respond to climate-related risks and opportunities over specified time horizons. This climate risk stress testing pilot program should include institutions such as agricultural, community banks, and non-systemically important regional banks.

Recommendation 4.9: Regulators should closely monitor international experience with climate risk stress testing of banks and insurers and apply relevant lessons to the U.S. context. U.S. regulators should engage in international forums, such as the NGFS, to ensure that climate risk stress testing conducted in the United States is comparable to similar exercises in other jurisdictions and avoid duplicative exercises for institutions with a multi-jurisdictional footprint.

Recommendation 4.10: Financial authorities should consider integrating climate risk into their balance sheet management and asset purchases, particularly relating to corporate and municipal debt.

Recommendation 4.11: The CFTC should:

- Undertake a program of research aimed at understanding how climate-related risks are impacting and could impact markets and market participants under CFTC oversight, including central counterparties, futures commission merchants, and speculative traders and funds; the research program should also cover how the CFTC's capabilities and supervisory role may need to adapt to fulfill its mandate in light of climate change and identify relevant gaps in the CFTC's regulatory and supervisory framework;

- Drawing on the conclusions of the research program above, review the extent to which existing CFTC rules are adequate to monitor and manage climate-related risks. For example, CFTC should review the extent to which rules for non-centrally cleared over-the-counter derivatives (NCD) are appropriate for monitoring and managing climate-related risks. It should also review rules related to capital and margin requirements of futures commission merchants and swap dealers, as well as initial margin and default fund rules, risk management rules, and capital requirements pertaining to central counterparties;

- Expand its own central counterparty stress testing to cover the operational continuity and organizational resilience of central counterparties, including organizational resilience of operations, contingency planning, and engineering resilience for facilities exposed to climate-related physical risks. Where central counterparties and market infrastructure are not within the CFTC's direct supervisory remit, the supervision of physical risks should be addressed by the relevant FSOC member in a consistent fashion; and

- As better understanding emerges of the risk-transmission pathways and of where the material climate risks lie, consider expanding the CFTC's risk management rules and related quarterly risk exposure reports to cover material climate-related risks.

Recommendation 4.12: State insurance regulators and insurance regulators' supervisory colleges, which are convened by regulators where an insurer or its subsidiaries or affiliates operate in multiple jurisdictions, should:

- Require insurers to assess how their underwriting activity and investment portfolios may be impacted by climate-related risks and, based on that assessment, require them to address and disclose these risks; and

- To facilitate the risk assessment mentioned in the point above, insurance regulators should conduct, or require insurance companies to conduct, climate risk stress tests and scenario analyses to evaluate potential financial exposure to both the physical and transition impacts of climate change; state insurance regulators should provide the scenarios, assumptions, and parameters for the stress testing exercise.

Recommendation 4.13: Regulators should require insurers to integrate consideration of climate risks into insurers' Enterprise Risk Management (ERM) and Own Risk Solvency Assessments (ORSA) processes.

Recommendation 4.14: Regulators should require credit rating agencies to disclose the extent to which their ratings take into account climate risk, including for issuers of corporate, municipal, and sovereign debt. This should include a disclosure of applicable methodologies for those credit rating products that consider climate risk.

Financial Market Utilities

Recommendation 4.15: Federal regulators should ensure that risk management standards governing the operations related to the payment, clearing, and settlement activities of FMUs incorporate measures to monitor and manage physical climate risks. The CFTC, in its capacity as an FSOC member, should recommend that the Council oversee and coordinate this process as it pertains to FMUs designated as systemically important.

Recommendation 4.16: The CFTC should review the extent to which financial market infrastructure—including but not limited to systemically important FMUs for which it is the primary regulator—is resilient against losses that could arise through the physical impacts of climate change.

Chapter 5

Recommendation 5.1: Financial regulators, in coordination with the private sector, should support the availability of consistent, comparable, and reliable climate risk data and analysis to advance the effective measurement and management of climate risk.

- Regulators and financial institutions should support the range of platforms for climate data and analysis, including improving public access to governmental data and expertise that can enable climate risk management. They should also support new and existing open source platforms, as well as proprietary efforts to develop new climate risk datasets and tools that leverage innovative technologies.

Recommendation 5.2: Financial regulators, in coordination with the private sector, should support the development of U.S.-appropriate standardized and consistent classification systems or taxonomies for physical and transition risks, exposure, sensitivity, vulnerability, adaptation, and resilience, spanning asset classes and sectors, in order to define core terms supporting the comparison of climate risk data and associated financial products and services.

- To develop this guidance, the United States should study the establishment of a Standards Developing Organization (SDO) composed of public and private sector members.
- Recognizing that this guidance will be specific to the United States, this effort should include international engagement in order to ensure coordination across global definitions to the extent practicable.

Recommendation 5.3: Financial regulators should proactively encourage capacity building for climate risk management. This should be consistent with the education and training practices supported by agencies in implementing the Sarbanes-Oxley Act of 2002. It should align with and aid in meeting regulator expectations around embedding climate risk in governance frameworks.

Chapter 6

Scenarios and Scenario Analysis

Climate scenario analysis should focus on potential material impacts to the institution's financial portfolio, whether loans, derivatives, or investments. In this context, the following guidelines should be useful:

Recommendation 6.1: Analyze more than one warming path. Various long-term paths for climate change exist and can be used for scenario analysis. Three common scenarios are (i) Paris-aligned (for example, consistent with limiting temperatures well below 2 degrees Celsius above pre-industrial levels), (ii) current trajectory and (iii) in-between (for example, late policy adoption with a more abrupt and disruptive response). Each will produce different impacts on institutional portfolios and provide insights that will help to more effectively manage risk, particularly bookends of best- and worst-case scenarios. Scenarios should include both shorter- and longer-horizon paths as appropriate.

Recommendation 6.2: Analyze disruptive policy. It is particularly important to analyze a scenario involving a major policy disruption. Transition scenarios have wide implications across the economy, industries, and markets. Unanticipated policies can abruptly strand long-lived capital assets or induce rapid reallocation of capital across sectors and industries. Increasing physical impacts may increase the risks of a disorderly transition as fires, floods, and

hurricanes, and the attendant shifts in public sentiment, force governments into unanticipated policy responses. Scenarios are therefore especially relevant for risk management.

Recommendation 6.3: Analyze both broad and specific impacts. Scenarios should capture the breadth of impacts but with a focus on materiality, covering a global perspective but enabling regional, country, and sectoral analysis appropriate to the firm's business.

Recommendation 6.4: Map macroeconomic and financial impacts. Scenarios should take into account macroeconomic and financial outcomes since these are likely to be most material to financial institutions. Coming up with additional temperature scenarios, for example, is less important than providing some common guidance on potential transmission mechanisms and implications for macroeconomic and financial factors.

Recommendation 6.5: Account for adaptation actions to the extent feasible. Tackling climate change necessarily involves myriad adjustments by a range of actors. Modeling the effects of such adaptation actions on portfolios is complex but may become more feasible with future technology and scenario modeling development.

Policymakers and Regulators

Recommendation 6.6: Prescribe a consistent and common set of broad climate risk scenarios, guidelines, and assumptions and mandate assessment against these scenarios, as described in Chapter 4. Regulators, in consultation with industry participants, external experts, and other stakeholders, should develop and prescribe a consistent set of broadly applicable scenarios, guidelines, and assumptions and require institutions to assess their exposure to those scenarios. Climate scenarios should be both plausible and relevant, all the while informed by climate science. Regulators should require a range of climate scenarios, including scenarios covering severe but plausible outcomes. Key assumptions (including policy pathways) and limitations should be transparent. Scenarios, assumptions, and guidelines should be updated as relevant factors are better understood and as policy and technology evolve. There should be a recognition that climate risk will manifest differently across various parts of the financial system.

Recommendation 6.7: Provide analytical discretion, to the extent practicable, as long as regulatory needs for consistency and comparability are met. Given the many unknowns and complexities inherent in modeling the economy, climate change science, and policy, regulated entities will need some discretion in how they perform their analysis based on the prescribed scenario. On the other hand, regulators need consistent approaches across firms so they can ensure risks are responsibly analyzed and reported. Investors would benefit from better comparability across scenario-related disclosures. To achieve a balance across these needs, regulators, in consultation with the firms they regulate, should specify key assumptions, scope, and the outputs they expect. As long as regulators' prescribed expectations are satisfied, regulators should allow financial institutions to provide additional context and analysis informed by the nature and complexity of their business.

Recommendation 6.8: Encourage domestic and global coordination across regulators to provide a coherent approach. This is an overarching theme of this report and especially applicable to the use of scenarios for risk management. Requiring entirely different stress scenario exercises from institutions operating under different jurisdictions would be costly while generating uncertain value. Harmonizing requirements and prioritizing practical, actionable exercises where feasible would be useful. The high costs associated with multiple regulatory regimes is a lesson of post-financial crisis regulation that can be applied now to climate risk.

Recommendation 6.9: Focus on materiality and risk management. Climate risks can manifest in many different ways. Institutions should focus on what matters for them and what decisions need to be made given their specific exposures and vulnerabilities. Such an approach facilitates effective risk management by laying out plausible ways climate risk-related financial losses could occur.

Recommendation 6.10: Ensure a mechanism for ongoing refinement and improvement. As science, data, tools, conditions, and policy change, it is important for regulatory guidelines to evolve as well. Data in particular is evolving rapidly. Creating a mechanism for regular updating, rather than relying on ad hoc adjustments, would be beneficial to ensure effective and pragmatic oversight. As regulators better understand the material risks in the system and their spillover effects across industries and markets, a mechanism for ongoing learning and timely refinement from these lessons learned will ensure they are most effectively managing risk across the system.

Capabilities and Applications

Given the uncertain nature of how the climate will evolve and the limited ability to rely on historical data and back-testing, robust scenario analysis calls for a new set of capabilities that combines statistical, financial, and environmental knowledge.

Recommendation 6.11: Tailor analysis to specific exposures. How an institution analyzes scenarios should be determined based on the unique nature of its portfolio. Not every scenario will be material to an institution's portfolio, depending on its largest asset concentrations, longest-dated assets, and highest potential sensitivities.

Recommendation 6.12: Use results to upgrade risk management capabilities. Regulators and risk managers can use insights coming from scenario analyses to strengthen and augment existing institutional risk management. Each institution should determine how to do so within its own framework but could include climate-related limits, adjustment to underwriting processes, client engagement, and climate risk appetite.

Recommendation 6.13: Beware of false precision. Scenario analysis can provide great value in understanding a range of potential outcomes (particularly between worst and best cases) and in identifying concentrations and relative sensitivities in a portfolio. But results, especially quantitative ones, will be illustrative, not precise, and so should be used accordingly in risk management decisions.

Risk Managers

Recommendation 6.14: Risk managers should develop in-house capabilities, as relevant and in line with best practices, to analyze climate scenarios, understand the key underlying assumptions, and recognize the limitations.

Recommendation 6.15: Firms and institutions should consider additional climate scenarios, guidelines and assumptions tailored to their specific needs and vulnerabilities, in addition to those provided by policymakers and regulators, to enhance internal risk management and decision-making. This can focus on generating decision-useful information for identifying and managing climate risk given their specific exposures and vulnerabilities.

Recommendation 6.16: The scope, depth, and complexity of the analyses performed by institutions should be proportionate to the materiality of the impact measured.

Chapter 7

In developing and implementing the recommendations below, financial regulators and the entities they oversee should consult with stakeholders, including investors, businesses, global peers, and other market intermediaries to create a U.S. climate disclosure regime. They also should closely coordinate with international bodies and foreign regulators to ensure the U.S. regime is aligned internationally. Because the understanding of climate risk remains at an early stage, any regulatory approach to climate-related disclosure should evolve in line with emerging best practices. Regulators should continually monitor the state of corporate climate disclosures, evolving clarity on the financial impacts of climate change and emerging best practices. This will allow regulators to continually monitor the quality of the information disclosed in a sophisticated manner, and issue supplemental guidance or begin rulemaking where needed to reflect emerging best practice and market needs. A mandatory, standardized disclosure framework for material climate risks, including guidance about what should be disclosed that is closely aligned with developing international consensus, would improve the utility and cost-effectiveness of disclosures.

Financial Market Regulators

Recommendation 7.1: All financial regulators should consider the following principles for effective disclosure, which are mainly derived from principles developed by the Task Force on Climate-related Financial Disclosures, when developing rules on climate risk disclosure, implementing existing rules or guidance, or seeking public comment on actions they should take:

- Disclosures should represent relevant information.
- Disclosures should be specific and complete.
- Disclosures should be clear, balanced, and understandable.

- Disclosures should be consistent over time.
- Disclosures should be comparable among companies within a sector, industry, or portfolio.
- Disclosures should be reliable, verifiable, and objective.
- Disclosures should be based on current consensus science (and updated as the science evolves) and the best available projections regarding climate change impacts.
- Disclosures should be provided on a timely basis.

Recommendation 7.2: Material climate risks must be disclosed under existing law, and climate risk disclosure should cover material risks for various time horizons. To address investor concerns around ambiguity on when climate change rises to the threshold of materiality, financial regulators should clarify the definition of materiality for disclosing medium- and long-term climate risks, including through quantitative and qualitative factors, as appropriate. Financial filings should include disclosure of any material financial risks from climate change in a consistent but non-boilerplate manner, as well as a qualitative description of how firms assess and monitor for potential changes in climate risks that may become material.

Recommendation 7.3: Regulators should consider additional, appropriate avenues for firms to disclose other substantive climate risks that do not pass the materiality threshold over various time horizons outside of their filings. Regulators should consider that a growing number of companies are creating greenhouse gas reduction targets and strategies out to the year 2035 or 2050, and targeted disclosure related to these items may be appropriate to facilitate robust efforts toward this positive trend.

Recommendation 7.4: Recognizing the costs associated with collecting, assessing and disclosing climate risk information, financial regulators should consider whether smaller companies could be provided a longer period of time to provide their initial disclosures, and the specific disclosures required of those companies could be different and less burdensome than those required of larger issuers.

Recommendation 7.5: In light of global advancements in the past 10 years in understanding and disclosing climate risks, regulators should review and update the SEC's 2010 *Guidance* on climate risk disclosure to achieve greater consistency in disclosure to help inform the market. Regulators should also consider rulemaking, where relevant, and ensure implementation of the *Guidance*. Such an update could incorporate advice on:

- Information that is needed from all companies in order to enable financial regulators to assess the systemic risks posed by climate change. Federal financial market regulators should work closely with prudential regulators to develop these rules.

- Industry-specific climate risk information. Rules should build from existing standards that provide industry-specific climate disclosure recommendations, for example, those developed by the TCFD, SASB, CDSB, the Physical Risks of Climate Change (P-ROCC) framework, and the Global Real Estate Sustainability Benchmark (GRESB) standards for real estate and infrastructure. Because these standards are already sophisticated, regulators do not need to create their own standards or metrics from scratch. Regulators should encourage stakeholders to partner with these standard-setting bodies to further develop, standardize, implement, and validate these metrics over time. Regulators should also acknowledge, in any rulemaking, that climate disclosure standards continue to evolve, and it could provide issuers flexibility, where appropriate, to adopt these evolving standards.

- Governance, risk management and scenario planning information that demonstrates how well companies are situated for a clean energy transition. Federal financial market regulators should work closely with prudential regulators to develop these rules. Scenario planning disclosure is discussed in Chapter 6. Regarding governance and risk management disclosure, regulators should consider the TCFD's recommendations and the Committee of Sponsoring Organizations of the Treadway Commission/World Business Council for Sustainable Development (COSO/WBCSD) guidance, applying enterprise risk management to environmental, social and governance-related risks.

Recommendation 7.6: Regulators should require listed companies to disclose Scope 1 and 2 emissions. As reliable transition risk metrics and consistent methodologies for Scope 3 emissions are developed, financial regulators should require their disclosure, to the extent they are material.

Recommendation 7.7: Regarding derivatives, financial regulators should examine the extent to which climate impacts are addressed in disclosures required of the entities they regulate and consider guidance and rulemaking if disclosure improvements are needed. This could include, for example, swap dealers registered with the CFTC, risk management rules that govern risk identification approaches; Quarterly Risk Exposure Reports, and business conduct rules that govern disclosure of material information to counterparties prior to entering into a swap.

Accounting Standards Regulators

Recommendation 7.8: Once climate risk disclosure standards are well advanced, accounting standards regulators should undertake a mapping exercise of the applicability of accounting standards to climate-related disclosure and subsequently issue guidance on disclosure, as appropriate. This would provide U.S. companies greater clarity about how climate risks may be integrated into financial statements.

Recommendation 7.9: The United States should direct the Federal Accounting Standards Advisory Board (FASAB) to study and pilot the development of climate-related federal accounting standards, disclosure procedures and practices for U.S. government departments, agencies and administrative units.

Municipal Securities Regulators

Recommendation 7.10: Municipal securities regulators should provide improved tools on the EMMA website to search for climate-related disclosure in municipal bond filings, similar to that provided for publicly traded companies, to allow better assessments of potential climate risk exposure in such assets and how they are being addressed.

Recommendation 7.11: Municipal securities regulators and the federal financial market regulator overseeing them should examine the quality of climate-related disclosures in municipal bonds' official statements and continuing disclosures, and whether the disclosure provided is adequate for market participants to assess any underlying climate risk exposure. If disclosure is found to be deficient, they should issue a public statement calling on key stakeholders to improve disclosure, including municipalities, municipal advisers, and banks.

Recommendation 7.12: Municipal securities regulators and federal financial market and prudential regulators should study how risks facing municipalities differ from—and could in some cases be more impactful than—risks facing issuers and explore options to enhance disclosure on these issues. Some municipalities already disclose information, as part of their bond issuances, about floods, storms, dam safety, droughts, wildfires, sea level rise, and risk mitigation efforts, and further study could demonstrate that such disclosure should be enhanced.

Chapter 8

Effective and well-functioning markets should allocate capital efficiently to net-zero emissions investments, spur innovation, and create and preserve quality jobs in a growing net-zero economy. These recommendations seek to meet these goals by improving the functioning of markets by reducing structural barriers and catalyzing private sector innovation. In undertaking these efforts, consideration should be paid to the distributional and equity impacts on low-to-moderate income households and marginalized communities. In addition, efforts should aim to facilitate an orderly transition, where possible, avoiding adding financial strain on already stressed sectors, including agricultural producers and commercial and industrial companies, among others.

Recommendation 8.1: The United States should consider integration of climate risk into fiscal policy, particularly for economic stimulus activities covering infrastructure, disaster relief, or other federal rebuilding. Current and ongoing fiscal policy decisions have implications for climate risk across the financial system.

Recommendation 8.2: The United States should consolidate and expand government efforts, including loan authorities and co-investment programs, that are focused on addressing market failures by catalyzing private sector climate-related investment. This effort could centralize existing clean energy and climate resilience loan authorities and co-investment programs into a coordinated federal umbrella.

Recommendation 8.3: Financial regulators should establish climate finance labs or regulatory sandboxes to enhance the development of innovative climate risk tools as well as financial products and services that directly integrate climate risk into new or existing instruments.

Recommendation 8.4: The United States and financial regulators should review relevant laws, regulations and codes and provide any necessary clarity to confirm the appropriateness of making investment decisions using climate-related factors in retirement and pension plans covered by the Employee Retirement Income Security Act (ERISA), as well as non-ERISA managed situations where there is fiduciary duty. This should clarify that climate-related factors—as well as ESG factors that impact risk-return more broadly—may be considered to the same extent as "traditional" financial factors, without creating additional burdens.

Recommendation 8.5: The CFTC should pursue the following activities to further catalyze climate finance market development:

- Survey market participants about their use of climate-related derivatives, the adequacy of product availability and market infrastructure, and the availability of data to incorporate climate impacts into existing and new instruments.
- Consider appropriate and targeted exemptions where needed to help facilitate coordination with other regulators and promote market development.
- Support the study and adoption of alternative execution methods, such as block trading, auction style markets, or incentive programs, to attract liquidity providers to make climate-related markets.
- Coordinate with other regulators to support the development of a robust ecosystem of climate-related risk management products.

References

Foreword

Coady, D., Parry, I., Le, N. P., & Shang, B. (2019). Global fossil fuel subsidies remain large: an update based on country-level estimates. *IMF Working Papers*, 19(89), 39. Retrieved from *https://www.imf.org/en/Publications/WP/Issues/2019/05/02/Global-Fossil-Fuel-Subsidies-Remain-Large-An-Update-Based-on-Country-Level-Estimates-46509*

Pei, S., Kandula, S., & Shaman, J. (2020). *Differential Effects of Intervention Timing on COVID-19 Spread in the United States*. Working Paper. National Institutes of Health Preprint. PMID: 32511526. Retrieved from *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7273294/*

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Bank for International Settlements (BIS)(2020). *Climate-related Financial Risks: a Survey on Current Initiatives*. Basel, CH.: Bank of International Settlements, Basel Committee on Banking Supervision. Retrieved from *https://www.bis.org/bcbs/publ/d502.pdf*

Brainard, L. (2019, November 8th). *Why Climate Change Matters for Monetary Policy and Financial Stability*. Remarks at "The Economics of Climate Change" Research Conference Sponsored by the Federal Reserve Bank of San Francisco. Washington, D.C.: Board of Governors of the Federal Reserve System. Retrieved from *https://www.federalreserve.gov/newsevents/speech/brainard20191108a.htm*

California State Teachers' Retirement System (CalSTRS)(2016, February 3rd). *CalSTRS Divests from U.S. Thermal Coal Companies*. West Sacramento, CA.: California State Teachers' Retirement System. Retrieved from *https://www.calstrs.com/news-release/calstrs-divests-us-thermal-coal-companies*

Carney, M. (2019). Remarks Given during the U.N. Secretary General's Climate Action Summit 2019. London, U.K.: Bank of England. Retrieved from *https://www.bankofengland.co.uk/-/media/boe/files/speech/2019/remarks-given-during-the-un-secretary-generals-climate-actions-summit-2019-mark-carney.pdf*

Cœuré, B. (2018). *Monetary Policy and Climate Change*. Frankfurt am Main, GR.: European Central Bank. Retrieved from *https://www.ecb.europa.eu/press/key/date/2018/html/ecb.sp181108.en.html*

Climate Action 100+ (CA100)(2019). *2019 Progress Report*. London, U.K.: Principles for Responsible Investment. Retrieved from *https://climateaction100.wordpress.com/progress-report/*

Daniel, K. D., Litterman, R. B., & Wagner, G. (2019). Declining CO_2 price paths. *Proceedings of the National Academy of Sciences*, 116(42), 20886-20891.

Debelle, G. (2019). *Climate Change and the Economy*. Sydney, AU.: Reserve Bank of Australia. Retrieved from *https://www.rba.gov.au/speeches/2019/sp-dg-2019-03-12.html*

Financial Stability Board (FSB)(2015). *Proposal for a Disclosure Task Force on Climate-related Risks*. Basel, CH.: Financial Stability Board. Retrieved from *https://www.fsb.org/wp-content/uploads/Disclosure-task-force-on-climate-related-risks.pdf*

Fink, L. (2020). *Sustainability as BlackRock's New Standard for Investing*. Letter to CEOs from the Global Executive Committee, January 14th. New York, NY.: BlackRock. Retrieved from *https://www.blackrock.com/corporate/investor-relations/blackrock-client-letter*

High-Level Commission on Carbon Prices (2017). *Report of the High-Level Commission on Carbon Prices*. Washington, D.C.: High-Level Commission on Carbon Prices, World Bank.

Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., Rasmussen, D.J., Muir-Wood, R., Wilson, P., Oppenheimer, M., & Larsen, K. (2017). Estimating economic damage from climate change in the United States. *Science*, 356(6345), 1362-1369. doi: 10.1126/science.aal4369

Interagency Working Group on the Social Cost of Greenhouse Gases (IWG)(2016). *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*. Washington, D.C.: U.S. Environmental Protection Agency. Retrieved from *https://www.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf*

Intergovernmental Panel on Climate Change (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., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M., & Waterfield, T. (eds.)]. Cambridge, U.K.: Intergovernmental Panel on Climate Change.

Lagarde, C. (2020). *Debate About the Annual Report*. Frankfurt am Main, GR.: European Central Bank. Retrieved from *https://www.ecb.europa.eu/press/key/date/2020/html/ecb.sp200211~f188a4e20f.en.html*

Central Banks and Supervisors Network for Greening the Financial System (NGFS)(2019). *Origin and Purpose*. Paris, FR.: NGFS Secretariat/Banque de France. Retrieved from *https://www.ngfs.net/en*

Central Banks and Supervisors Network for Greening the Financial System (NGFS)(2020). *Membership*. Paris, FR.: NGFS Secretariat/Banque de France. Retrieved from *https://www.ngfs.net/en/about-us/membership*

Norges Bank, (2019, March 3rd). *Divestments*. Oslo, NR.: Norges Bank Investment Management. Retrieved from *https://www.nbim.no/en/the-fund/responsible-investment/divestments/*

Principles for Responsible Investment (PRI)(2020). *Net-Zero Asset Owners Alliance*. London, U.K.: United Nations Environment Programme. Retrieved from *https://www.unepfi.org/net-zero-alliance/*

Revesz, R. L., Howard, P. H., Arrow, K., Goulder, L. H., Kopp, R. E., Livermore, M. A., & Sterner, T. (2014). Global warming: Improve economic models of climate change. *Nature*, 508(7495), 173.

Ritchie, H., & Roser, M. (2017). CO_2 and Greenhouse Gas Emissions. In *Our World in Data*. Oxford, U.K.: Oxford Martin School, University of Oxford.

Stern, N. (2007). *The Economics of Climate Change: The Stern Review*. Cambridge, U.K.: Cambridge University Press.

Sustainable Insurance Forum (SIF)(2020). *Members*. Geneva, CH.: Sustainable Insurance Forum, U.N. Environment Program. Retrieved from *https://www.sustainableinsuranceforum.org/members*

Sustainable Insurance Forum (SIF) & International Association of Insurance Supervisors (IAIS) (2018). *Issues Paper on Climate Change Risks to the Insurance Sector*. Geneva, CH.: International Association of Insurance Supervisors/ Sustainable Insurance Forum, U.N. Environment Program. Retrieved from *https://b9ea8c1e-dc19-4d5f-b149-9b1ea4b8d050.filesusr.com/ugd/eb1f0b_0e5afc146e44459b907f0431b9e3bf21.pdf*

Sustainable Insurance Forum (SIF) & International Association of Insurance Supervisors (IAIS) (2020). *Issues Paper on Implementation of the Recommendations of the Task Force on Climate-related Financial Disclosures*. Geneva, CH.: International Association of Insurance Supervisors/ Sustainable Insurance Forum, U.N. Environment Program. Retrieved from *https://b9ea8c1e-dc19-4d5f-b149-9b1ea4b8d050.filesusr.com/ugd/eb1f0b_365cc83062254d509c20d79313143868.pdf*

Task Force on Climate-related Financial Disclosures (TCFD)(2020a). *FAQs*. Basel, CH.: Financial Stability Board, Bank of International Settlements. Retrieved from *https://www.fsb-tcfd.org/about/#*

Task Force on Climate-related Financial Disclosures (TCFD)(2020b). *More than 1,000 Global Organizations Declare Support for the Task Force on Climate-related Financial Disclosures and its Recommendations*. Basel, CH.: Financial Stability Board, Bank of International Settlements. Retrieved from *https://www.fsb-tcfd.org/wp-content/uploads/2020/02/PR-TCFD-1000-Supporters_FINAL.pdf*

United Nations Framework Convention on Climate Change (UNFCCC)(2015). *U.S. Cover Note, INDC and Accompanying Information*. Bonn, GR.: United Nations Framework Convention on Climate Change. Retrieved from *https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/United%20States%20of%20America/1/U.S.%20Cover%20Note%20INDC%20and%20Accompanying%20Information.pdf*

U.S. Energy Information Agency (EIA)(2020). *Annual Energy Outlook 2020*. Washington, D.C.: U.S. Department of Energy, U.S. Energy Information Agency.

U.S. Environmental Protection Agency (EPA)(2020). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018*. EPA 430-R-20-002. Washington, D.C.: U.S. Environmental Protection Agency.

U.S. Global Change Research Program (USGCRP)(2018). *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. Washington, D.C.: U.S. Global Change Research Program. doi:10.7930/NCA4.2018

Wilkins, C. (2019). *Financial Stability in an Uncertain World (Full Remarks)*. Ottawa, CA.: Bank of Canada. Retrieved from *https://www.bankofcanada.ca/2019/11/financial-stability-uncertain-world/*

World Bank (2020). *State and Trends of Carbon Pricing 2020*. Washington, D.C.: World Bank Group.

Wuebbles, D.J., Fahey, D.W., Hibbard, K.A., DeAngelo, B., Doherty, S., Hayhoe, K., Horton, R., Kossin, J.P., Taylor, P.C., Waple, A.M. & Weaver, C.P. (2017): Executive Summary. In *Climate Science Special Report: Fourth National Climate Assessment, Volume I* [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. Washington, D.C.: U.S. Global Change Research Program. pp. 12-34. doi:10.7930/J0DJ5CTG

Chapter 2

Ajami, N, Habicht, H.., Fewell, B., Lattimer, T., & Ng, T., (2018). *Water Finance: The Imperative for Water Security and Economic Growth*. Water in the West, Stanford University. Palo Alto, CA.: Stanford University. Retrieved from *https://waterinthewest.stanford.edu/sites/default/files/Water_Finance_Water_Security_Economic_Growth.pdf*

American Society of Civil Engineers (ASCE)(2017). *2017 Infrastructure Report Card: A Comprehensive Assessment of America's Infrastructure*. Washington, D.C.: American Society of Civil Engineers. Retrieved from *https://www.infrastructurereportcard.org/*

Atanasova, C., & Schwartz, E. S. (2019). *Stranded Fossil Fuel Reserves and Firm Value*. NBER Working Paper No. 6497. Cambridge, MA.: National Bureau of Economic Research. Retrieved from *https://www.nber.org/papers/w26497*

Attavanich, W., McCarl, B. A., Ahmedov, Z., Fuller, S. W., & Vedenov, D. V. (2013). Effects of climate change on US grain transport. *Nature Climate Change*, 3(7), 638-643.

Antóni, J., Kimuari, S., Lankoskii, J. & Cattane, A. (2012). *A Comparative Study of Risk Management in Agriculture under Climate Change*. OECD Food, Agriculture and Fisheries Papers, No. 58. Paris, FR.: OECD Publishing. doi:10.1787/5k94d6fx5bd8-en

Bakker, C., Zaitchik, B. F., Siddiqui, S., Hobbs, B. F., Broaddus, E., Neff, R. A., & Parker, C. L. (2018). Shocks, seasonality, and disaggregation: Modelling food security through the integration of agricultural, transportation, and economic systems. *Agricultural Systems*, 164(1), 165-184. doi: 10.1016/j.agsy.2018.04.005

Baldauf, M., Garlappi, L., & Yannelis, C. (2020). Does climate change affect real estate prices? Only if you believe in it. *The Review of Financial Studies*, 33(3), 1256-1295. doi: 10.1093/rfs/hhz073

Bastidas-Arteaga, E. (2018). Reliability of reinforced concrete structures subjected to corrosion-fatigue and climate change. *International Journal of Concrete Structures and Materials*, 12(1), 10. doi: 10.1186/s40069-018-0235-x

Bein, T., Karagiannidis, C., & Quintel, M. (2019). Climate change, global warming, and intensive care. *Intensive Care Medicine*, 46, 485–487. doi:10.1007/s00134-019-05888-4

Bernstein, A., Gustafson, M. T., & Lewis, R. (2019). Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics*, 134(2), 253-272. doi:10.1016/j.jfineco.2019.03.013

Bertolotti, A., Basu, D., Akallal, K., & Deese, B. (2019, March). *Climate Risk in the US Electric Utility Sector: A Case Study*. Working Paper. New York, NY.: BlackRock. Retrieved from *https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3347746*

BlackRock Investment Institute (BII)(2019). *Getting Physical: Scenario Analysis for Assessing Climate Risks*. New York, NY.: BlackRock. Retrieved from *https://www.blackrock.com/us/individual/literature/whitepaper/bii-physical-climate-risks-april-2019.pdf*

Bolton, P., Despres, M., da Silva, L. A. P., Samama, F., & Svartzman, R. (2020). *The Green Swan: Central Banking and Financial Stability in the Age of Climate Change*. Basel, CH.: Bank of International Settlements/Banque du France.

Bolton, P., & Kacperczyk, M. T. (2019). *Do Investors Care about Carbon Risk?*. Working Paper. Retrieved from *https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3398441*

Bullock, C., Ard, K., & Saalman, G. (2018). Measuring the Relationship between State Environmental Justice Action and Air Pollution Inequality, 1990–2009. *Review of Policy Research*, 35(3), 466-490.

Burke, M., & Emerick, K. (2016). Adaptation to climate change: Evidence from US agriculture. *American Economic Journal: Economic Policy*, 8(3), 106-40.

Brusset, X., & Bertrand, J. L. (2018). Hedging weather risk and coordinating supply chains. *Journal of Operations Management*, 64, 41-52. doi: 10.1016/j.jom.2018.10.002

Carney, M. (2018, April 6th) *A Transition in Thinking and Action. Remarks at the International Climate Risk Conference for Supervisors*. Amsterdam, NL.: De Nederlandsche Bank. Retrieved from *https://www.bis.org/review/r180420b.pdf*

Christensen, P., Gillingham, K., & Nordhaus, W. (2018). Uncertainty in forecasts of long-run economic growth. *Proceedings of the National Academy of Sciences*, 115(21), 5409-5414.

Dai, A., & Zhao, T. (2017). Uncertainties in historical changes and future projections of drought. Part I: estimates of historical drought changes. *Climatic Change*, 144(3), 519-533.

Day, E., Fankhauser, S., Kingsmill, N., Costa, H., & Mavrogianni, A. (2019). Upholding labour productivity under climate change: an assessment of adaptation options. *Climate Policy*, 19(3), 367-385. doi:10.1080/14693062.2018.1517640

Desai, S. P., Harris, C. A., & Gordon, J. (2019). The Economic Impact of Hurricane Evacuations on a Coastal Georgia Hospital: A Case Study. *Frontiers in Public Health*, 7, 149. doi: 10.3389/fpubh.2019.00149

Dunne, J. P., Stouffer, R. J., & John, J. G. (2013). Reductions in labour capacity from heat stress under climate warming. *Nature Climate Change*, 3(6), 563-566. doi:10.1038/nclimate1827

Ebi, K.L., Balbus, J.M., Luber, G., Bole, A., Crimmins, A., Glass, G., Saha, S., Shimamoto, M.M., Trtanj, J., & White-Newsome, J.L. (2018). Human Health. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. Washington, D.C.: U.S. Global Change Research Program. doi:10.7930/NCA4.2018.CH14

Engle, R. F., Giglio, S., Kelly, B., Lee, H., & Stroebel, J. (2020). Hedging climate change news. *The Review of Financial Studies*, 33(3), 1184-1216. doi:10.1093/rfs/hhz072

Fant, C., Boehlert, B., Strzepek, K., Larsen, P., White, A., Gulati, S., & Martinich, J. (2020). Climate change impacts and costs to US electricity transmission and distribution infrastructure. *Energy*, 195, 116899. doi:10.1016/j.energy.2020.116899

Garnache, C., & Guilfoos, T. (2019). *A City on Fire? Effect of Salience on Risk Perceptions*. Working Paper. Retrieved from *https://pdfs.semanticscholar.org/9220/a841e5b7b0b153a1213ae2c9111e6a9e131c.pdf*

Gary, S. N. (2019). Best Interests in the Long Term: Fiduciary Duties and ESG Integration. *University of Colorado Law Review*, 90, 731.

Giglio, S., Maggiori, M., & Stroebel, J. (2015a). Very long-run discount rates. *The Quarterly Journal of Economics*, 130(1), 1-53. doi:10.1093/qje/qju036

Giglio, S., Maggiori, M., Rao, K., Stroebel, J., & Weber, A. (2015b). *Climate change and long-run discount rates: Evidence from real estate*. No. w21767. Cambridge, MA.: National Bureau of Economic Research.

Gilmore, E. A., & St. Clair, T. (2018). Budgeting for climate change: Obstacles and opportunities at the US state level. *Climate Policy*, 18(6), 729-741. doi:10.1080/14693062.2017.1366891

Goldsmith-Pinkham, P. S., Gustafson, M., Lewis, R., & Schwert, M. (2019, October 30th). *Sea Level Rise and Municipal Bond Yields*. SSRN Working Paper: 3478364. doi:10.2139/ssrn.3478364

Goldstein, A., Turner, W. R., Gladstone, J., & Hole, D. G. (2019). The private sector's climate change risk and adaptation blind spots. *Nature Climate Change*, 9(1), 18-25. doi: 10.1038/s41558-018-0340-5

Gordon, K. (ed.)(2014). *The Economic Risks of Climate Change in the United States: A Climate Risk Assessment for the United States*. New York, NY.: Risky Business Project. Retrieved from *https://riskybusiness.org/site/assets/uploads/2015/09/RiskyBusiness_Report_WEB_09_08_14.pdf*

Gowda, P., Steiner, J. L., Olson, C., Boggess, M., Farrigan, T., & Grusak, M. A. (2018). Agriculture and Rural Communities. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. Washington, D.C.: U.S. Global Change Research Program. doi:10.7930/NCA4.2018.CH10

Graff Zivin, J., & Neidell, M. (2014). Temperature and the allocation of time: Implications for climate change. *Journal of Labor Economics*, 32(1), 1-26. doi:10.1086/671766

Gubernot, D. M., Anderson, G. B., & Hunting, K. L. (2014). The epidemiology of occupational heat exposure in the United States: a review of the literature and assessment of research needs in a changing climate. *International Journal of Biometeorology*, 58(8), 1779-1788.

Gundlach, J. (2020). Climate risks are becoming legal liabilities for the energy sector. *Nature Energy*, 5, 94-97. doi:10.1038/s41560-019-0540-x

Ha-Duong, M. (2020). *Stranded assets risk derails Vietnam's plan for new coal power plants*. IAEE Energy Forum, First Quarter 2020. Cleveland, OH.: International Association for Energy Economics.

Hallegatte, S., Rentschler, J., & Rozenberg, J. (2019). *Lifelines: The Resilient Infrastructure Opportunity*. Washington, D.C.: The World Bank.

Hallegatte, S., & Rozenberg, J. (2017). Climate change through a poverty lens. *Nature Climate Change*, 7(4), 250-256. doi: 10.1038/nclimate3253

Harvey, H., Orvis, R., & Rissman, J. (2018). *Designing Climate Solutions: A Policy Guide for Low-carbon Energy*. Washington, D.C.: Island Press.

Hauer, M. E. (2017). Migration induced by sea-level rise could reshape the US population landscape. *Nature Climate Change*, 7(5), 321-325.

Hill, A. C., & Martinez-Diaz, L. (2019). *Building a Resilient Tomorrow: How to Prepare for the Coming Climate Disruption*. New York, NY.: Oxford University Press.

Houser, T., Hsiang, S., Kopp, R., Larsen, K., Delgado, M., Jina, A., Mastrandrea, M., Mohan, S., Muir-Wood, R., Rasmussen, D.J., & Rising, J. (2015). *Economic Risks of Climate Change: An American Prospectus*. New York, NY.: Columbia University Press.

Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., Rasmussen, D.J., Muir-Wood, R., Wilson, P., Oppenheimer, M., & Larsen, K. (2017). Estimating economic damage from climate change in the United States. *Science*, 356(6345), 1362-1369. doi: 10.1126/science.aal4369

International Energy Agency (IEA)(2020). *The Oil and Gas Industry in Energy Transitions: Insights from IEA Analysis*. Paris, FR.: International Energy Agency.

Issler, P., Stanton, R., Vergara-Alert, C., & Wallace, N. (2020). *Mortgage Markets with Climate-Change Risk: Evidence from Wildfires in California*. SSRN Working Paper: 3511843. doi: 10.2139/ssrn.3511843

Jacobs, J.M., M. Culp, L. Cattaneo, P. Chinowsky, A. Choate, S. DesRoches, S. Douglass, & R. Miller (2018). Transportation. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. Washington, D.C.: U.S. Global Change Research Program. doi:10.7930/NCA4.2018.CH12

Keenan, J. M. (2018). *Climate Adaptation Finance and Investment in California*. London, UK.: Routledge.

Keenan, J. M. (2019). A Climate Intelligence Arms Race in Financial Markets. *Science*, 365(6459), 1240-1243. doi:10.1126/science.aay8442

Keenan, J.M. & Bradt, J.T. (2020). Underwaterwriting: From Theory to Empiricism in Regional U.S. Coastal Mortgage Markets. *Climatic Change*. doi: 10.1007/s10584-020-02734-1

Keenan, J. M., Hill, T., & Gumber, A. (2018). Climate gentrification: from theory to empiricism in Miami-Dade County, Florida. *Environmental Research Letters*, 13(5), 054001. doi: 10.1088/1748-9326/aabb32/meta

Kefford, B. M., Ballinger, B., Schmeda-Lopez, D. R., Greig, C., & Smart, S. (2018). The early retirement challenge for fossil fuel power plants in deep decarbonisation scenarios. *Energy Policy*, 119, 294-306. doi:10.1016/j.enpol.2018.04.018

Kim, H., Marcouiller, D. W., & Woosnam, K. M. (2018). Rescaling social dynamics in climate change: The implications of cumulative exposure, climate justice, and community resilience. *Geoforum*, 96, 129-140. doi:10.1016/j.geoforum.2018.08.006

Klein, J. (2015). *Potential Liability of Governments for Failure to Prepare for Climate Change*. White Paper, Sabin Center for Climate Change Law. New York, NY.: Columbia University School of Law. doi:10.2139/ssrn.2667240

Liang, X. Z., Wu, Y., Chambers, R. G., Schmoldt, D. L., Gao, W., Liu, C., & Kennedy, J. A. (2017). Determining climate effects on US total agricultural productivity. *Proceedings of the National Academy of Sciences*, 114(12), E2285-E2292.

Lim-Camacho, L., Plagányi, É. E., Crimp, S., Hodgkinson, J. H., Hobday, A. J., Howden, S. M., & Loechel, B. (2017). Complex resource supply chains display higher resilience to simulated climate shocks. *Global Environmental Change*, 46, 126-138. doi: 10.1016/j.gloenvcha.2017.08.011

Lipton, D., Rubenstein, M.A., Weiskopf, S.R., Carter, S., Peterson, J., Crozier, L., Fogarty, M., Gaichas, S., Hyde, K.J.W., Morelli, T.L., Morisette, J., Moustahfid, H., Muñoz, R., Poudel, R., Staudinger, M.D., Stock, C., Thompson, L., Waples, R., & Weltzin, J.F. (2018). Ecosystems, Ecosystem Services, and Biodiversity. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. Washington, D.C.: U.S. Global Change Research Program. doi:10.7930/NCA4.2018.CH7

Lundgren, K., Kuklane, K., Gao, C., & Holmer, I. (2013). Effects of heat stress on working populations when facing climate change. *Industrial Health*, 51(1), 3-15.

MacWilliams, J.J., La Monaca, S., & Kobus, J. (2019, August). *PG&E: Market and Policy Perspectives on the First Climate Change Bankruptcy*. Center on Global Energy Policy. New York, NY.: Columbia University, School of International and Public Affairs. Retrieved from *https://energypolicy.columbia.edu/sites/default/files/file-uploads/PG&E-CGEP_Report_081419-3.pdf*

Marjanac, S., & Patton, L. (2018). Extreme weather event attribution science and climate change litigation: an essential step in the causal chain?. *Journal of Energy & Natural Resources Law*, 36(3), 265-298.

Masters, R., Anwar, E., Collins, B., Cookson, R., & Capewell, S. (2017). Return on investment of public health interventions: a systematic review. *Journal of Epidemiology & Community Health*, 71(8), 827-834. doi:10.1136/jech-2016-208141

Maxwell, K., Julius, S., Grambsch, A., Kosmal, A., Larson, L., & Sonti, N. (2018). Built Environment, Urban Systems, and Cities. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K., & Stewart, B.C. (eds.)]. Washington, D.C.: U.S. Global Change Research Program. doi:10.7930/NCA4.2018.CH10

McCoy, S. J., & Walsh, R. P. (2018). Wildfire risk, salience & housing demand. Journal of *Environmental Economics and Management*, 91(1), 203-228. doi: 10.1016/j.jeem.2018.07.005

Mendelevitch, R., Hauenstein, C., & Holz, F. (2019). The death spiral of coal in the US: will changes in US Policy turn the tide?. *Climate Policy*, 19(10), 1310-1324. doi: 10.1080/14693062.2019.1641462

Mercure, J. F., Pollitt, H., Viñuales, J. E., Edwards, N. R., Holden, P. B., Chewpreecha, U., & Knobloch, F. (2018). Macroeconomic impact of stranded fossil fuel assets. *Nature Climate Change*, 8(7), 588-593. doi:10.1038/s41558-018-0182-1

Mian, A., Rao, K., & Sufi, A. (2013). Household balance sheets, consumption, and the economic slump. *The Quarterly Journal of Economics*, 128(4), 1687-1726. doi:10.1093/qje/qjt020

Morris, A. C., Kaufman, N., & Doshi, S. (2020). Revenue at Risk in Coal-Reliant Counties. NBER Chapters. In *Environmental and Energy Policy and the Economy, Volume 2*. Cambridge, MA.: National Bureau of Economic Research, Inc.

National Academies of Sciences, Engineering, and Medicine (NASEM)(2016). *Attribution of Extreme Weather Events in the Context of Climate Change*. Washington, D.C.: National Academies Press. doi: 10.17226/21852

Network for Greening the Financial System (NGFS) (2019a). *Macroeconomic and Financial Stability Implications of Climate Change*. Technical Supplement to the First Comprehensive Report. Paris, FR.: NGFS Secretariat/Banque de France.

Network for Greening the Financial System (NGFS) (2019b). *A Call for Action Climate Change as a Source of Financial Risk*. First Comprehensive Report. Paris, FR.: NGFS Secretariat/Banque de France.

Olszynski, M., Mascher, S., & Doelle, M. (2017). From smokes to smokestacks: Lessons from tobacco for the future of climate change liability. *Georgetown International Environmental Law Review*, 30(1), 1-45.

Ouazad, A., & Kahn, M. E. (2019). *Mortgage Finance in the Face of Rising Climate Risk*. NBER Working Paper No. 26322. Cambridge, MA.: National Bureau of Economic Research. Retrieved from *https://www.nber.org/papers/w26322*

Ovaere, M., Heylen, E., Proost, S., Deconinck, G., & Van Hertem, D. (2019). How detailed value of lost load data impact power system reliability decisions. *Energy Policy*, 132, 1064-1075. doi:10.1016/j.enpol.2019.06.058

Porter, J.R., Liyong, X., Challinor, A., Cochrane, K., Howden, M., Iqbal, M.M., Lobell, D., & Travasso, M.I. (2014). Chapter 7: Food Security and Food Production Systems. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, U.K.: Cambridge University Press.

Principles for Responsible Investing (PRI)(2019). *The Inevitable Policy Response: Policy Forecasts*. London, U.K.: United Nations Environmental Programme Finance Initiative.

Ritchie, J., & Dowlatabadi, H. (2017). The 1000 GtC coal question: Are cases of vastly expanded future coal combustion still plausible?. *Energy Economics*, 65, 16-31.

Rojas-Downing, M. M., Nejadhashemi, A. P., Harrigan, T., & Woznicki, S. A. (2017). Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management*, 16, 145-163.

Rosa, I. (2018, May 10th). *Federal Crop Insurance: Program Overview for the 115thCongress*. CRS Report R45193. Washington, D.C.: Congressional Research Service. Retrieved from *https://crsreports.congress.gov/product/pdf/R/R45193/4*

Sabin Center for Climate Change Law, Columbia Law School (Sabin Center)(2020). *Climate Litigation Database*. New York, NY.: Columbia University. Retrieved from *www.climatecasechart.com*.

Schmeltz, M. T., Petkova, E. P., & Gamble, J. L. (2016). Economic burden of hospitalizations for heat-related illnesses in the United States, 2001–2010. *International Journal of Environmental Research and Public Health*, 13(9), 894. doi:10.3390/ijerph13090894

Shi, L., & Varuzzo, A. M. (2020). Surging seas, rising fiscal stress: Exploring municipal fiscal vulnerability to climate change. *Cities*, 100, 102658. doi:10.1016/j.cities.2020.102658

Siders, A. R. (2019). Social justice implications of US managed retreat buyout programs. *Climatic Change*, 152(2), 239-257. doi:10.1007/s10584-018-2272-5

S&P Global (2019). *Understanding Climate Risk at the Asset Level: The Interplay of Transition and Physical Risks*. New York, NY.: S&P Trucost Limited.

Stewart, M. G., & Deng, X. (2015). Climate impact risks and climate adaptation engineering for built infrastructure. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems*, Part A: Civil Engineering, 1(1), 04014001. doi: 10.1061/AJRUA6.0000809

Stroebel, J., & Vavra, J. (2019). House prices, local demand, and retail prices. *Journal of Political Economy*, 127(3), 1391-1436. doi:10.1086/701422

Taylor, R. A. J., Herms, D. A., Cardina, J., & Moore, R. H. (2018). Climate change and pest management: unanticipated consequences of trophic dislocation. *Agronomy*, 8(1), 7. doi: 10.3390/agronomy8010007

U.S. Department of Agriculture (USDA)(2020). *Ag and Food Sectors and the Economy*. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service. Retrieved from *https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ag-and-food-sectors-and-the-economy/*

U.S. Department of Energy (DOE)(2017). Transforming the Nation's Electricity System: The Second Instalment of the Quadrennial Energy Review. (DOE/EPSA-0008. Washington, D.C.: U.S. Department of Energy. Retrieved from *https://energy.gov/epsa/quadrennial-energy-review-second-installment*

U.S. Energy Information Agency (EIA)(2020). *Annual Energy Review: Total Energy*. Washington, D.C.: U.S. Department of Energy, U.S. Energy Information Agency.

U.S. Environmental Protection Agency (EPA)(2017). *Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment*. EPA 430-R-17-001. Washington, D.C.: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency (EPA)(2018). *6th Drinking Water Infrastructure Needs Survey and Assessment*. Washington, D.C.: U.S. Environmental Protection Agency.

Vizcarra, H. V. (2018). Climate-Related Disclosure and Litigation Risk in the Oil & Gas Industry: Will State Attorneys General Investigations Impede the Drive for More Expansive Disclosures. *Vermont Law Review*, 43, 733.

Vizcarra, H. V. (2020). The Reasonable Investor and Climate-Related Information: Changing Expectations for Financial Disclosures. *The Environmental Law Reporter*, 50 (2), 10106.

Walthall, C., Backlund, P., Hatfield, J., Lengnick, L., Marshall, E., Walsh, M., Adkins, S., Aillery, M., Ainsworth, E.A., Amman, C. & Anderson, C.J., (2012). *Climate Change and Agriculture in the United States: Effects and Adaptation*. USDA Technical Bulletin 1935. Washington, D.C.: U.S. Department of Agriculture. Retrieved from *https://lib.dr.iastate.edu/cgi/viewcontent.cgi?article=1000&context=ge_at_reports*

Wondmagegn, B. Y., Xiang, J., Williams, S., Pisaniello, D., & Bi, P. (2019). What do we know about the healthcare costs of extreme heat exposure? A comprehensive literature review. *Science of the Total Environment*, 657, 608-618. doi:10.1016/j.scitotenv.2018.11.479

World Bank (2019). *Population Growth (Annual %)*. Washington, D.C.: World Bank Group. Retrieved from *https://data.worldbank.org/indicator/SP.POP.GROW*

Wu, X., Lu, Y., Zhou, S., Chen, L., & Xu, B. (2016). Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment International*, 86, 14-23. doi: 10.1016/j.envint.2015.09.007

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D. B., Huang, Y., Yao, Y., Bassu, S., Ciais, P., & Durand, J. L. (2017). Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences*, 114(35), 9326-9331. doi: 10.1073/pnas.1701762114

Zurich Insurance Group Ltd. (Zurich)(2018). *Managing the Impacts of Climate Change: Risk Management Responses*. Zurich, CH.: Zurich Insurance Group Ltd.

Chapter 3

Adrian, T., Covitz, D., & Liang, N. (2014). Financial Stability Monitoring. *Federal Reserve Bank of New York Staff Reports*, No. 601. New York, NY.: Federal Reserve Bank of New York. Retrieved from *https://www.newyorkfed.org/medialibrary/media/research/staff_reports/sr601.pdf*

Agnese, L., & Simone, M. (Eds.). (2017). *Achieving Financial Stability: Challenges to Prudential Regulation* (Vol. 61). Chicago, IL.: World Scientific / Federal Reserve Bank of Chicago.

Barnett, M., Brock, W., & Hansen, L. P. (2020). Pricing uncertainty induced by climate change. *The Review of Financial Studies*, 33(3), 1024-1066.

Bernstein, A., Gustafson, M. T., & Lewis, R. (2019). Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics*, 134(2), 253-272. doi:10.1016/j.jfineco.2019.03.013

BlackRock Investment Institute (BII)(2019). *Getting Physical: Scenario Analysis for Assessing Climate Risks*. New York, NY.: BlackRock. Retrieved from *https://www.blackrock.com/us/individual/literature/whitepaper/bii-physical-climate-risks-april-2019.pdf*

Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature*, 527, 235-339. doi:10.1038/nature15725

Crane-Droesch, A., Marshall, E., Rosch, S., Riddle, A., Cooper, J., & Wallander, S. (2019). *Climate Change and Agricultural Risk Management Into the 21st Century*. No. 291962. Washington, D.C.: U.S. Department of Agriculture, Economic Research Service.

De Nederlandsche Bank (DNB)(2017). *Waterproof? An exploration of climate-related risks for the Dutch financial sector*. Amsterdam, NL.: De Nederlandsche Bank. Retrieved from *https://www.dnb.nl/en/binaries/Waterproof_tcm47-363851.pdf*

Depository Trust & Clearing Corporation (DTCC)(2014). *Mitigating Risk | DTCC 2013 Annual Report*. New York, NY.: Depository Trust & Clearing Corporation. Retrieved from *https://www.dtcc.com/annuals/2013/mitigating-risk/index.php*

Federal Deposit Insurance Corporation (FDIC)(2019). *2019 Risk Review*. Washington, D.C.: Federal Deposit Insurance Corporation. Retrieved from *https://www.fdic.gov/bank/analytical/risk-review/full.pdf*

Financial Stability Oversight Council (FSOC)(2019). *2019 Annual Report*. Washington, D.C.: Financial Stability Oversight Council. Retrieved from *https://home.treasury.gov/system/files/261/FSOC2019AnnualReport.pdf*

Gallagher, J., & Hartley, D. (2015). *Household Finance after a Natural Disaster: The Case of Hurricane Katrina*. Working Papers, WP 14-06R. Cleveland, OH.: Federal Reserve Bank of Cleveland. Retrieved from *https://www.clevelandfed.org/newsroom-and-events/publications/working-papers/2015-working-papers/wp-1406r-household-finance-after-a-natural-disaster*

Hartley, D., Packis, E., & Weintraut, B. (2019). Flooding and Finances: Hurricane Harvey's Impact on Consumer Credit. *Chicago Fed Letter*, No. 415. Chicago, IL.: Federal Reserve Bank of Chicago. Retrieved from *https://www.chicagofed.org/publications/chicago-fed-letter/2019/415*

Hill, A. C., & Martinez-Diaz, L. (2019). *Building a Resilient Tomorrow: How to Prepare for the Coming Climate Disruption*. New York, NY.: Oxford University Press.

Hong, H., Karolyi, G. A., & Scheinkman, J. A. (2020). Climate finance. *The Review of Financial Studies*, 33(3), 1011-1023.

Humston, T. L. (2019). Slowing Agricultural Markets Highlight the Importance of Sound Risk Management Principles. *Community Banking Connections*. Washington, D.C.: The Federal Reserve System. Retrieved from *https://www.communitybankingconnections.org/articles/2019/i1/slowing-agricultural-markets*

International Monetary Fund (IMF), Bank for International Settlements (BIS), & Financial Stability Board (FSB) (2009). *Report to G20 Finance Ministers and Governors – Guidance to Assess the Systemic Importance of Financial Institutions, Markets and Instruments: Initial Considerations*. Washington, D.C.: International Monetary Fund. Retrieved from *https://www.imf.org/external/np/g20/pdf/100109.pdf*

International Monetary Fund (IMF)(2020). *Global Financial Stability Report*. Washington, D.C.: International Monetary Fund. Retrieved from *https://www.imf.org/en/Publications/GFSR/Issues/2020/04/14/Global-Financial-Stability-Report-April-2020-49020*

Jorgenson, D. W., Goettle, R. J., Ho, M. S., & Wilcoxen, P. J. (2018). The welfare consequences of taxing carbon. *Climate Change Economics*, 09(1), 1840013. doi:10.1142/S2010007818400134

Koren, J.F. (2018, December 5th). Insurer Merced went belly up after Camp fire. Here's what policyholders need to know. *Los Angeles Times*. Retrieved from *https://www.latimes.com/business/la-fi-merced-insurance-customers-20181204-story.html*

Kousky, C. (2018). Financing flood losses: A discussion of the national flood insurance program. *Risk Management and Insurance Review*, 21(1), 11-32. doi:10.1111/rmir.12090

Kuran, T., & Sunstein, C. R. (1998). Availability cascades and risk regulation. *Stanford Law Review*, 51, 683-768.

Landon-Lane, J., Rockoff, H., & Steckel, R. H. (2011). Droughts, Floods and Financial Distress in the United States. *The Economics of Climate Change: Adaptations Past and Present*, 73–98. Cambridge, MA.: National Bureau of Economic Research. Retrieved from *https://www.nber.org/chapters/c11983.pdf*

Morgan Stanley (2019). *Rising Flood Risk: How Much and at What Cost?* New York, NY: Morgan Stanley.

Morris, A. C., Kaufman, N., & Doshi, S. (2019). *The Risk of Fiscal Collapse in Coal-Reliant Communities*. Center on Global Energy Policy & The Brookings Institution. New York, NY.: Columbia University, School of International and Public Affairs. Retrieved from *https://www.brookings.edu/wp-content/uploads/2019/07/RiskofFiscalCollapseinCoalReliantCommunities-CGEP_Report_080619.pdf*

Morris, A. C. (2016). *The Challenge of State Reliance on Revenue from Fossil Fuel Production*. Washington, D.C.: The Brookings Institution. Retrieved from *https://www.brookings.edu/wp-content/uploads/2016/08/state-fiscal-implications-of-fossil-fuel-production-0809216-morris.pdf*

Mortgage Bankers Association (MBA)(2019). *Commercial/Multifamily Quarterly Databook | Q3 2019*. Washington, D.C.: Mortgage Bankers Association. Retrieved from *http://mba.informz.net/MBA/data/images/Research/CMF%20Databook/3Q19CMFDatabook.pdf*

Municipal Securities Rulemaking Board (MSRB)(2019). *Municipal Securities: Financing the Nation's Infrastructure*. Washington, D.C.: Municipal Securities Rulemaking Board. Retrieved from *http://www.msrb.org/~~~/media/Files/Resources/MSRB-Infrastructure-Primer.ashx*

Oppedahl, D. (2019, August). *AgLetter*: August 2019. Chicago, IL.: Federal Reserve Bank of Chicago. Retrieved from *https://www.chicagofed.org/publications/agletter/2015-2019/august-2019*

Ouazad, A., & Kahn, M. E. (2019). *Mortgage Finance in the Face of Rising Climate Risk*. NBER Working Paper No. 26322. Cambridge, MA.: National Bureau of Economic Research. Retrieved from *https://www.nber.org/papers/w26322*

Tariq, Z., & Duren, C. (2019). Flooding may cause credit problems at Midwest banks. *S&P Global*. Retrieved from *https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/51102824*

Tartar, A. & Pickert, R. (2019). A Third of America's Economy is Concentrated in Just 31 Counties. *Bloomberg*. Retrieved from: *https://www.bloomberg.com/graphics/2019-us-gdp-concentration-counties/*

U.N. Environment Programme Finance Initiative (UNEP FI)(2017). *Drought Stress Testing: Making Financial Institutions More Resilient to Environmental Risks*. Franfurt, GR.: U.N. Environment Programme. Retrieved from *https://naturalcapital.finance/wp-content/uploads/2018/11/Drought-Stress-Testing-Tool-FULL-REPORT.pdf*

U.S. Department of Agriculture (UDSA)(2019). *USDA Farm Programs Help Farmers and Ranchers During 2019 Challenges*. Washington, D.C.: U.S. Department of Agriculture. Retrieved from *https://www.fsa.usda.gov/news-room/news-releases/2019/usda-farm-programs-help-farmers-and-ranchers-during-2019-challenges*

U.S. Department of the Treasury (Treasury)(2017). *Financial Stability Oversight Council Designations*. Washington, D.C.: U.S. Department of the Treasury. Retrieved from *https://www.treasury.gov/press-center/press-releases/Documents/PM-FSOC-Designations-Memo-11-17.pdf*

Chapter 4

California Department of Insurance (CDI)(2018). *Climate Risk Carbon Initiative*. Sacramento, CA.: California Department of Insurance. Retrieved from *https://interactive.web.insurance.ca.gov/apex_extprd/f?p=250:1:8443176587472*

California Department of Insurance (CDI) & University of California, Berkeley School of Law Center for Law, Energy & the Environment (UC Berkeley CLEE) (2018). *Trial by Fire: Managing Climate Risks Facing Insurers in the Golden State*. Berkeley, CA.: University of California, Berkeley School of Law Center for Law, Energy & the Environment. Retrieved from *https://www.law.berkeley.edu/wp-content/uploads/2018/09/Trial-by-Fire-September-2018.pdf*

Dodd-Frank Wall Street Reform and Consumer Protection Act (DFA)(2010). 12 USC § 5301-5641.

Gelles, D. (2016). S.E.C. Is Criticized for Lax Enforcement of Climate Risk Disclosure. *The New York Times*. Retrieved from *https://www.nytimes.com/2016/01/24/business/energy-environment/sec-is-criticized-for-lax-enforcement-of-climate-risk-disclosure.html*

Mutua, D.C. (2020). ESG is Increasingly Important in Credit Ratings, Moody's Says. *Bloomberg News*. Retrieved from: *https://www.bloomberg.com/news/articles/2020-04-14/esg-is-increasingly-important-in-credit-ratings-moody-s-says*

National Association of Insurance Commissioners (NAIC)(2019). *NAIC Climate Risk Disclosure Survey*. Kansas City, MO.: National Association of Insurance Commissioners. Retrieved from *http://www.insurance.ca.gov/0250-insurers/0300-insurers/0100-applications/ClimateSurvey/index.cfm*

Office of Financial Research (OFR)(2017). *Cybersecurity and Financial Stability: Risks and Resilience*. OFR Viewpoint 17-01. Washington, D.C.: Office of Financial Research. Retrieved from *https://www.financialresearch.gov/viewpoint-papers/files/OFRvp_17-01_Cybersecurity.pdf*

Stevenson, C. (2019). *Leaving Investors in the Dark: The SEC's Growing Silence on Guidance Related to the Business and Legal Developments on Climate Change*. Georgetown Environmental Law Review Blog. Washington, D.C.: Georgetown University. Retrieved from *https://www.law.georgetown.edu/environmental-law-review/blog/leaving-investors-in-the-dark-the-secs-growing-silence-on-guidance-related-to-the-business-and-legal-developments-on-climate-change/*

U.S. Commodity Futures Trading Commission (CFTC) (2020). *Commodity Exchange Act & Regulations*. Washington, D.C.: U.S. Commodity Futures Trading Commission. Retrieved from *https://www.cftc.gov/LawRegulation/CommodityExchangeAct/index.htm*

U.S. Securities and Exchange Commission (SEC)(1989). *SEC Interpretation: Management's Discussion and Analysis of Financial Condition and Results of Operations; Certain Investment Company Disclosures*. Release Nos. 33-6835; 34-26831; IC-16961; FR-36. Washington, D.C.: U.S. Securities and Exchange Commission. Retrieved from *https://www.sec.gov/rules/interp/33-6835.htm*

U.S. Securities and Exchange Commission (SEC)(2010). *Commission Guidance Regarding Disclosure Related to Climate Change*. Release Nos. 33-9106; 34-61469; FR-82. Washington, D.C.: U.S. Securities and Exchange Commission Retrieved from *https://www.sec.gov/rules/interp/2010/33-9106.pdf*

Chapter 5

American Meteorological Society (AMS)(2019). *Full, Open and Timely Access to Data: A Policy Statement of the American Meteorological Society*. Washington, D.C.: American Meteorological Society. Retrieved from *www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/statements-of-the-ams-in-force/full-open-and-timely-access-to-data/*

Berg, F., Kölbel, J., & Rigobon, R. (2019). *Aggregate Confusion: The Divergence of ESG Ratings*. MIT Sloan School Working Paper, 19(5822). doi:10.2139/ssrn.3438533

Dietz, S., Bowen, A., Dixon, C., & Gradwell, P. (2016). 'Climate value at risk' of global financial assets. *Nature Climate Change*, 6, 676-679. doi:10.1038/nclimate2972

Federal Emergency Management Agency (FEMA) (2009). *Acronyms Abbreviations & Terms: A Capability Assurance Job Aid*. FEMA P-52. Washington, D.C.: U.S. Department of Homeland Security.

Gary, S. N. (2019). Best Interests in the Long Term: Fiduciary Duties and ESG Integration. *University of Colorado Law Review*, 90, 731-801.

International Organization of Standardization (ISO)(2019). *ISO 14090:2019. Adaptation to climate change — Principles, requirements and guidelines*. Geneva, CH.: International Organization of Standardization. Retrieved from *https://www.iso.org/standard/68507.html*

Keenan, J.M. (2018). *Climate Adaptation Finance and Investment in California*. London, U.K.: Routledge.

Linnenluecke, M. K. (2017). Resilience in business and management research: A review of influential publications and a research agenda. *International Journal of Management Reviews*, 19(1), 4-30.

McKnight, B., & Linnenluecke, M. K. (2019). Patterns of firm responses to different types of natural disasters. *Business & Society*, 58(4), 813-840.

Sahebjamnia, N., Torabi, S. A., & Mansouri, S. A. (2015). Integrated business continuity and disaster recovery planning: Towards organizational resilience. *European Journal of Operational Research*, 242(1), 261-273.

Schanzenbach, M. M., & Sitkoff, R. H. (2020). Reconciling Fiduciary Duty and Social Conscience: The Law and Economics of ESG Investing by a Trustee. *Stanford Law Review*, 72, 381.

U.S. Global Change Research Program (USGCRP) (2020). *Climate Change: Glossary*. Washington, D.C.: U.S. Global Change Research Program. Retrieved from *https://www.globalchange.gov/climate-change/glossary*

Winston, A. (2014). Resilience in a hotter world. *Harvard Business Review*, 92(4), 56-64.

Chapter 6

Jupiter Intelligence (2020). *Uncovering New Risks from Extreme Floods to Electric Substations in Harris County*, TX. San Mateo, CA.: Jupiter Intelligence. Retrieved from *https://jupiterintel.com/wp-content/uploads/2020/02/Jupiter_HoustonSpecialReport_20200214.pdf*

Network for Greening the Financial System (NGFS) (2020a). *The Macroeconomic and Financial Stability Impacts of Climate Change: Research Priorities*. Technical Document. Paris, FR.: NGFS Secretariat/Banque de France. Retrieved from *https://www.ngfs.net/sites/default/files/medias/documents/ngfs_research_priorities_final.pdf*

Network for Greening the Financial System (NGFS) (2020b). *Guide to Climate Scenario Analysis for Central Banks and Supervisors*. Paris, FR.: NGFS Secretariat/Banque de France. Retrieved from *https://www.ngfs.net/sites/default/files/medias/documents/ngfs_guide_scenario_analysis_final.pdf*

Network for Greening the Financial System (NGFS) (2020c). *NGFS Climate Scenarios for Central Banks and Supervisors*. Paris, FR.: NGFS Secretariat/Banque de France. Retrieved from *https://www.ngfs.net/sites/default/files/medias/documents/ngfs_climate_scenarios_final.pdf*

Network for Greening the Financial System (NGFS) (2020d). *NGFS Climate Scenarios Database: Technical Documentation*. Paris, FR.: NGFS Secretariat/Banque de France. Retrieved from *https://www.ngfs.net/sites/default/files/ngfs_climate_scenario_technical_documentation_final.pdf*

Task Force on Climate-related Financial Disclosures (TCFD)(2017). *Recommendations for the Task on Climate-related Financial Disclosures: Final Report*. Basel, CH.: Financial Stability Board, Bank of International Settlements. Retrieved from *https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-2017-TCFD-Report-11052018.pdf*

U.N. Environment Programme Finance Initiative (UNEP FI) & Oliver Wyman (2018). *Extending Our Horizons: Assessing Credit Risk and Opportunity in a Changing Climate, Part I: Transition-related Risks and Opportunities*. London, U.K.: UNEP Financial Initiative / Oliver Wyman.

Vaze, P., Meng, A., & Giuliani, D. (2019). *Greening the Financial System: Tilting the Playing Field, The Role of Central Banks*. London, U.K.: Climate Bonds Initiative / Centre for Sustainable Finance, University of London.

Chapter 7

Anderson, N. (2019, November). *IFRS Standards® and Climate-related Disclosures*. In Brief. London, UK.: International Financial Reporting Standards (IFRS) Foundation. Retrieved from *https://cdn.ifrs.org/-/media/feature/news/2019/november/in-brief-climate-change-nick-anderson.pdf?la=en*

Australian Accounting Standards Board (AUASB) and Auditing and Assurance Standards Board (AASB)(2018). *Climate-related and other emerging risks disclosures: assessing financial statement materiality using AASB/IASB Practice Statement 2*. Canberra, AU.: Australian Accounting Standards Board. Retrieved from *https://www.aasb.gov.au/admin/file/content102/c3/AASB_AUASB_Joint_Bulletin_Finished.pdf*

Bolton, P., Despres, M., da Silva, L. A. P., Samama, F., & Svartzman, R. (2020). *The Green Swan: Central Banking and Financial Stability in the Age of Climate Change*. Basel, CH.: Bank of International Settlements/Banque du France.

California Public Employees' Retirement System (CalPERS), et al. (2007). *Petition for Interpretive Guidance on Climate Risk Disclosure. A Petition Before the U.S. Securities and Exchange Commission*. Washington, D.C.: U.S. Securities and Exchange Commission. Retrieved from *https://www.sec.gov/rules/petitions/2007/petn4-547.pdf*

California Public Employees' Retirement System (CalPERS)(2019). *CalPERS' Governance & Sustainability Principles*. Sacramento, CA.: California Public Employees' Retirement System. Retrieved from *https://www.calpers.ca.gov/docs/forms-publications/governance-and-sustainability-principles.pdf*

Canadian Securities Administrators (CSA)(2019). *CSA Staff Notice 51-358 Reporting of Climate Change-related Risks*. Montreal, QC.: Canadian Securities Administrators.

Climate Action 100+ (CA100)(2019). *2019 Progress Report*. London, U.K.: Principles for Responsible Investment. Retrieved from *https://climateaction100.wordpress.com/progress-report/*

CDP (2020). *Mission Statement: What We Do*. London, U.K.: CDP. Retrieved from *https://www.cdp.net/en/info/about-us/what-we-do*

Comtois, J. (2019, November 12th). Institutional investors see ESG as part of their fiduciary duty – survey. *Pensions & Investments*. Retrieved from *https://www.pionline.com/esg/institutional-investors-see-esg-part-their-fiduciary-duty-survey*

Corporate Reporting Dialogue (CRD)(2019). *Driving Alignment in Climate-related Reporting*. London, U.K.: CDP. Retrieved from *https://corporatereportingdialogue.com/wp-content/uploads/2019/09/CRD_BAP_Report_2019.pdf*

European Commission (EC)(2019, June). *Guidelines on Reporting Climate-related Information*. Brussel, BR.: European Commission, Directorate-General for Financial Stability, Financial Services and Capital Markets Union. Retrieved from *https://ec.europa.eu/finance/docs/policy/190618-climate-related-information-reporting-guidelines_en.pdf*

Expert Panel on Sustainable Finance, Canadian Government (Canada)(2019). *Final Report of the Expert Panel on Sustainable Finance–Mobilizing Finance for Sustainable Growth*. June 14th, 2019. Ottawa, CA.: Canadian Government. Retrieved from *https://www.canada.ca/en/environment-climate-change/services/climate-change/expert-panel-sustainable-finance.html*

Fink, L. (2020). *Sustainability as BlackRock's New Standard for Investing*. Letter to CEOs from the Global Executive Committee, January 14th. New York, NY.: BlackRock. Retrieved *https://www.blackrock.com/corporate/investor-relations/blackrock-client-letter*

Global Reporting Initiative (GRI)(2019). *Global Reporting Initiative, Annual Accounts, January 1st – December 31st 2018*. Amsterdam, NL.: Global Reporting Initiative. Retrieved from *https://www.globalreporting.org/SiteCollectionDocuments/2019/GRI%20AnnualAccounts_FY2018.pdf*

Global Reporting Initiative (GRI)(2020). *GRI Sustainability Reporting Standards: Database Overview*. Amsterdam, NL.: Global Reporting Initiative. Retrieved from *https://www.globalreporting.org/information/sustainability-reporting/Pages/gri-standards.aspx*

Government Finance Officers Association (GFOA)(2020). *Primary Market Disclosure*. Chicago, IL.: Government Finance Officers Association.

Hamilton, L. A. (2010). Canary in the Coal Mine: Can the Campaign for Mandatory Climate Risk Disclosure Withstand the Municipal Bond Market's Resistance to Regulatory Reform. *William Mitchell Law Review*, 36, 1014. Retrieved from *https://open.mitchellhamline.edu/cgi/viewcontent.cgi?article=1356&context=wmlr*

Her Majesty's Government, United Kingdom (HM Government)(2019). *Green Finance Strategy: Transforming Finance for a Greener Future*. London, U.K.: HM Treasury/ Department for Business, Energy & Industrial Strategy. Retrieved from *https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/820284/190716_BEIS_Green_Finance_Strategy_Accessible_Final.pdf*

Hoffner, D. (2016, July 21st). *CalPERS, Letter to SEC re: File No. S7-06-16*. Release Nos. 33-10064, 33-77599. Business and Financial Disclosure Required by Regulation S-K. Washington, D.C.: U.S. Securities and Exchange Commission. Retrieved from *https://www.sec.gov/comments/s7-06-16/s70616-267.pdf*

Idzelis, C. (2019, June 11th). Investors See 'Material Risk' in Ignoring ESG. *Institutional Investor*. Retrieved from *https://www.institutionalinvestor.com/article/b1ft39r3dw3hv0/Investors-See-Material-Risk-in-Ignoring-ESG*

International Integrated Reporting Council (IIRC)(2019). *IIRC Integrated Report 2018*. London. Retrieved from *https://integratedreporting.org/integratedreport2018/download/pdf/IIRC_INTEGRATED_REPORT_2018.pdf*

International Organization of Securities Commission (IOSCO)(2019, January 18th). *Statement on Disclosure of ESG Matters by Issuers*. Madrid, ES.: International Organization of Securities Commission. Retrieved from *https://www.iasplus.com/en-ca/news/part-i-ifrs/copy3_of_01/iosco-esg*

Investor Agenda Founding Partners (IAFP)(2019, December). *Global Investor Statement to Governments on Climate Change*. COP25 Madrid. London, U.K.: Investor Agenda Founding Partners. Retrieved from *https://theinvestoragenda.org/wp-content/uploads/2019/12/191201-GISGCC-FINAL-for-COP25.pdf*

Krueger, P. (2015). *Climate change and firm valuation: Evidence from a quasi-natural experiment*. Swiss Finance Institute Research Paper. Geneva, CH.: University of Geneva.

Mahoney, R. & Gargiulo, D. (2019). *The State of Climate Risk Disclosure: A Survey of U.S. Companies*. Chicago, IL.: DFin/Society for Corporate Governance.

National Federation of Municipal Analysts (NFMA) (2019). *Disclosure Guidelines*. Pittsburgh, PA.: National Federation of Municipal Analysts. Retrieved from *https://www.nfma.org/disclosure-guidelines*

Ohm, C., Jensen, L.Z., & Jørgensen, R. (2020). *Climate Risk Disclosure Barometer 2020*. Copenhagen, DK.: Ernst & Young Global Limited.

Olsen, R. (2018, December 6th). *Opening Remarks at 2018 Municipal Securities Disclosure Conference*. U.S. Securities and Exchange Commission: Washington, D.C. Retrieved from *https://www.sec.gov/news/public-statement/statement-olsen-120618*

Rhodes, W., & Magrani, K. (2019). *Climate Change Disclosure in Municipal Offerings*. Philadelphia, PA.: Ballard Spahr, LLP. Retrieved from *https://www.ballardspahr.com/alertspublications/articles/whitepaper-climate-change-cybersecurity-disclosure-municipal-offerings*

Rozin, L. (2019, October 21). *ESG Risks Trickle into Financial Filings*. Arlington, VA.: National Association of Corporate Directors. Retrieved from *https://blog.nacdonline.org/posts/esg-risks-trickle-into-financial-filings*

Sustainability Accounting Standards Board (SASB)(2016). *Climate Risk Technical Bulletin*. Technical Bulletin#: TB001-10182016. San Francisco, CA.: Sustainability Accounting Standards Board. Retrieved from *https://www.sasb.org/wp-content/uploads/2019/08/Climate-Risk-Technical-Bulletin-web.pdf*

Sustainability Accounting Standards Board (SASB) (2020). *Companies Reporting with SASB Standards: List*. San Francisco, CA.: Sustainability Accounting Standards Board. Retrieved from *https://www.sasb.org/company-use/*

Taraporevala, C. (2020, January 28th). *CEO's Letter on our Proxy Voting Agenda*. Letter to Board. Boston, MA.: State Street Advisors. Retrieved from *https://www.ssga.com/us/en/individual/etfs/insights/informing-better-decisions-with-esg*

Task Force on Climate-related Financial Disclosures (TCFD)(2017). *Recommendations for the Task on Climate-related Financial Disclosures: Final Report*. Basel, CH.: Financial Stability Board, Bank of International Settlements. Retrieved from *https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-2017-TCFD-Report-11052018.pdf*

Task Force on Climate-related Financial Disclosures (TCFD)(2019a). *Good Practice Handbook*. Basel, CH.: Financial Stability Board, Bank of International Settlements. Retrieved from *https://www.sasb.org/knowledge-hub/tcfd-good-practice-handbook/*

Task Force on Climate-related Financial Disclosures (TCFD)(2019b). *Status Report*. Basel, CH.: Financial Stability Board, Bank of International Settlements. Retrieved from *https://www.fsb-tcfd.org/wp-content/uploads/2019/06/2019-TCFD-Status-Report-FINAL-053119.pdf*

U.S. Department of the Treasury (Treasury)(2020). *2019 Financial Report of the United States Government*. Washington, D.C.: U.S. Department of the Treasury. Retrieved from *https://www.fiscal.treasury.gov/files/reports-statements/financial-report/2019/FR-02272020(Final).pdf*

U.S. Government Accountability Office (GAO)(2018, February). *Climate-related Risks: SEC Has Taken Steps to Clarify Disclosure Requirements*. Washington, D.C.: U.S. Government Accountability Office. Retrieved from *https://www.gao.gov/assets/700/690197.pdf*

U.S. Securities and Exchange Commission (SEC)(2002). *Certification of Disclosure in Companies' Quarterly and Annual Reports*. 2002-33-8124. Washington, D.C.: U.S. Securities and Exchange Commission. Retrieved from *https://www.sec.gov/rules/final/33-8124.htm*

U.S. Securities and Exchange Commission (SEC)(2010). *Common Guidance regarding Disclosure Related to Climate Change*. 2010-33-9106. Washington, D.C.: U.S. Securities and Exchange Commission. Retrieved from *https://www.sec.gov/rules/interp/2010/33-9106.pdf*

U.S. Securities and Exchange Commission (SEC)(2018). *The Road Ahead: Municipal Securities Disclosure In An Evolving Market. Panel Discussion Transcript*. Municipal Securities Conference, December 6, 2018. Washington, D.C.: U.S. Securities and Exchange Commission. Retrieved from *https://www.sec.gov/spotlight/municipalsecurities/municipal-securities-conference-120618-transcript.pdf*

U.S. Securities and Exchange Commission (SEC) (2020). *Recommendation from the Investor-as-Owner Subcommittee of the SEC Investor Advisory Committee Relating to ESG Disclosure*. Washington, D.C.: U.S. Securities and Exchange Commission, Investor-as-Owner Subcommittee of the SEC Investor Advisory Committee Relating to ESG Disclosure. Retrieved from *https://www.sec.gov/spotlight/investor-advisory-committee-2012/recommendation-of-the-investor-as-owner-subcommittee-on-esg-disclosure.pdf*

Chapter 8

Advanced Research Projects Agency – Energy (ARPA-E)(2020). ARPA-E Impact. Washington, D.C.: U.S. Department of Energy. Retrieved from *https://arpa-e.energy.gov/?q=site-page/arpa-e-impact*

Chestney, N. (2020, January 16th). Green bond issuance hit record $255 billion last year, research shows. *Reuters*. Retrieved from *https://www.reuters.com/article/us-greenbonds-issuance/green-bond-issuance-hit-record-255-billion-last-year-research-shows-idUSKBN1ZF1GD*

California Department of Insurance (CDI) and UC Berkeley School of Law Center for Law, Energy & the Environment (UC Berkley CLEE)(2018). *Trial by Fire: Managing Climate Risks Facing Insurers in the Golden State*. Sacramento, CA.: California Department of Insurance. Retrieved from *http://www.insurance.ca.gov/0400-news/0100-press-releases/2018/upload/nr106TrialbyFire090618.pdf*

Clark, G. L., Feiner, A., & Viehs, M. (2015). *From the Stockholder to the Stakeholder: How Sustainability Can Drive Financial Outperformance*. SSRN Working Paper: 2508281. Social Science Research Network. doi:10.2139/ssrn.2508281

Friede, G., Busch, T., & Bassen, A. (2015). ESG and financial performance: Aggregated evidence from more than 2000 empirical studies. *Journal of Sustainable Finance & Investment*, 5, 210–233. Retrieved from *https://doi.org/10.1080/20430795.2015.1118917*

Hale, J. (2020, January 10th). Sustainable Fund Flows in 2019 Smash Previous Records. *Morningstar*. Retrieved from *https://www.morningstar.com/articles/961765/sustainable-fund-flows-in-2019-smash-previous-records*

Harvard Management Company, Inc. (HMC)(2020). *Harvard Endowment Net-Zero Portfolio Commitment*. Boston, MA.: Harvard Management Company, Inc. Retrieved from *https://www.hmc.harvard.edu/content/uploads/2020/04/Net-Zero-Commitment.pdf*

International Renewable Energy Agency (IRENA)(2019). *Global Energy Transformation: A Roadmap to 2050*. Abu Dhabi, UAE: International Renewable Energy Agency.

Keenan, J. M. (2019). A Climate Intelligence Arms Race in Financial Markets. *Science*, 365(6459), 1240-1243. doi:10.1126/science.aay8442

Khan, M., Serafeim, G., & Yoon, A. (2016). Corporate Sustainability: First Evidence on Materiality. *The Accounting Review*, 91(6), 1697–1724. doi:10.2308/accr-51383

Morgan Stanley (2015a). *Sustainable Reality: Understanding the Performance of Sustainable Investment Strategies*. New York, NY.: Morgan Stanley Institute for Sustainable Investing.

Morgan Stanley (2015b). *Sustainable Signals: The Individual Investors Perspective*. New York, NY.: Morgan Stanley Institute for Sustainable Investing.

Morningstar (2020). *Global Sustainable Fund Flows*. Retrieved from *https://www.morningstar.com/content/dam/marketing/shared/pdfs/Research/Global_ESG_Q1_Flow_Report.pdf*

New York Green Bank (2020). *Metrics, Reporting & Evaluation: Quarterly Report No. 23*. Albany, NY.: New York Green Bank. Retrieved from *https://greenbank.ny.gov/-/media/greenbanknew/files/2020-Q1-Quarterly-Metrics-Report.PDF?la=en*

Stanford University (2020). *Board of Trustees commits to accelerating transition to net-zero greenhouse gas emissions, reports major reduction in fossil fuel investments*. Palo Alto, CA.: Stanford University. Retrieved from *https://news.stanford.edu/2020/06/12/trustees-commit-accelerating-transition-to-net-zero-greenhouse-gas-emissions/*

The Nature Conservancy (2019). *Wildfires and Forest Resilience: The Case for Ecological Forestry in the Sierra Nevada*. Sacramento, CA.: The Nature Conservancy. Retrieved from: *https://www.scienceforconservation.org/assets/downloads/WildfireForestResilience_2019_Kelsey_2.pdf*

U.S. Commodity Futures Trading Commission (CFTC) (2011). *Report on the Oversight of Existing and Prospective Carbon Markets*. Washington, D.C.: U.S. Commodity Futures Trading Commission, Working Group for the Study of Oversight of Carbon Markets. Retrieved from *https://www.cftc.gov/sites/default/files/idc/groups/public/@swaps/documents/file/dfstudy_carbon_011811.pdf*

U.S. Commodity Futures Trading Commission (CFTC) (2019, June 27th). *CFTC Announces LabCFTC Accelerator and Second FinTech Conference*. Release Number 7949-19. Washington, D.C.: U.S. Commodity Futures Trading Commission. Retrieved from *https://www.cftc.gov/PressRoom/PressReleases/7949-19*

U.S. Department of Energy (DOE)(2020). *Annual Portfolio Status Report: Fiscal Year 2019*. Washington, D.C.: U.S. Department of Energy. Retrieved from *https://www.energy.gov/sites/prod/files/2020/04/f73/DOE-LPO-APSR-2019-FINAL.pdf*

U.S. Department of Labor (DOL)(2018). *Interpretive Bulletins 2016-01 and 2015-01*. Field Assistance Bulletin No. 2018-01. Washington, D.C.: Employee Benefits Security Administration, U.S. Department of Labor. Retrieved from *https://www.dol.gov/agencies/ebsa/employers-and-advisers/guidance/field-assistance-bulletins/2018-01*

U.S. Department of Labor (DOL)(2020). *Financial Factors in Selecting Plan Investments*. A Proposed Rule from the Employee Benefits Security Administration. Washington, D.C.: U.S. Department of Labor, Employee Benefits Security Administration. Retrieved from *https://www.federalregister.gov/documents/2020/06/30/2020-13705/financial-factors-in-selecting-plan-investments*

U.S. Securities and Exchange Commission (SEC)(2020). *Request for Comment: Release Nos. IC_33809; File No. S7-04-20*. Washington, D.C.: U.S. Securities and Exchange Commission. Retrieved from *https://www.sec.gov/rules/other/2020/ic-33809.pdf*

Wood Mackenzie (2019). *Deep Decarbonisation: the Multi-Trillion-Dollar Question*. Boston MA.: Wood Mackenzie, Verisk.

World Federation of Exchanges (2019). *Sustainability & Commodity Derivatives*. White Paper. London, U.K.: World Federation of Exchanges. Retrieved from *https://www.world-exchanges.org/storage/app/media/research/Studies_Reports/wfe-commodity-derivatives-sustainability-final-wpaper-200819.pdf*

Appendix

Appendix Table 1: Sample of Multi-Sector Efforts to Increase Climate Data Availability		
Initiative	**Mission**	**Website**
Aqueduct	Aqueduct maps water risks such as floods, droughts, and stress, using open-source, peer reviewed data.	*https://www.wri.org/aqueduct*
Climate Data Online (CDO)	Maintained by the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information, the CDO provides free access to NOAA's archive of weather and climate data.	*https://www.ncdc.noaa.gov/cdo-web/*
Climate Explorer	The Climate Explorer provides graphs and maps of historical and projected climate variables for counties across the United States.	*https://crt-climate-explorer.nemac.org/*
ClimateWatch	ClimateWatch provides open data sets, visualizations and customized analyses to support stakeholders.	*https://www.climatewatchdata.org/*
Food and Agriculture Organization of the United Nations (FAO)	FAO maintains a variety of data centers including FAOSTAT which provides food and agriculture statistics (including crop, livestock and forestry sub-sectors) for over 245 countries and territories and the Food and Agriculture Microdata Catalogue (FAM) which provides access to micro data sets collected through farm and household surveys.	*http://www.fao.org/statistics/en/*

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Appendix Table 1: Sample of Multi-Sector Efforts to Increase Climate Data Availability *(continued)*		
Initiative	**Mission**	**Website**
Future of Sustainable Data Alliance (FSDA)	FSDA works to identify and accelerate the reliable, actionable ESG data and related technology that is needed for improved investor decision-making.	*http://solutions.refinitiv.com/futureofsustainabledata*
GeoAsset Project	GeoAsset is a public goods endeavor focused on making accurate, comparable, and comprehensive asset-level data tied to ownership publicly available across all major sectors and geographies.	*https://spatialfinanceinitiative.com/geoasset-project/*
Global Energy Monitor (GEM)	GEM organizes the production of asset-level data sets for fossil fuel sectors.	*https://globalenergymonitor.org*
U.S. EPA Greenhouse Gas Reporting Program (GHGRP)	GHGRP requires reporting of emissions data from 8,000 facilities covering large GHG emissions sources, fuel and industrial gas supplies, and CO_2 injection sites in the United States. The Facility Level Information on GreenHouse gases Tool (FLIGHT) leverages the GHGRP data into a visual tool to quickly filter data in a variety of ways, including by facility, industry, location, or gas.	*https://www.epa.gov/ghgreporting*
Oasis Hub	Oasis Hub is an aggregator for catastrophe, extreme weather and environmental risk data, tools and services, as well as provider of data set enhancement, development and data aggregation services.	*https://oasishub.co*
OS-Climate	OS-Climate aims to aggregate the best available data, modeling, and computing and data science worldwide into an AI-enhanced physical-economic model that functions like an operating system, enabling powerful applications for climate-integrated investing.	*https://www.os-climate.org*

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Appendix Table 1: Sample of Multi-Sector Efforts to Increase Climate Data Availability *(continued)*		
Initiative	**Mission**	**Website**
Power Explorer	Power Explorer aims to serve as the most comprehensive source for understanding the world's power systems and their impacts on development and environmental challenges.	*http://powerexplorer.org*
U.S. Climate Resilience Toolkit (USCRT)	USCRT serves as multi-sector platform for case studies, data sets, digital tools, and other resources for a variety of domestic stakeholders.	*https://toolkit.climate.gov/*
World Bank Sovereign ESG Data Portal	Data platform that provides country-level sustainability performance information to increase transparency and support investment aligned with sustainable development.	*https://databank.worldbank.org/source/environment-social-and-governance-(esg)-data*

Members of the Climate-Related Market Risk Subcommittee

The CFTC seeks to ensure that all of its advisory committee and subcommittee memberships are fairly balanced. To that end, the selection of the Climate-Related Market Risk Subcommittee members was consistent with the MRAC Federal Advisory Committee Act Charter and Membership Balance Plan. The Subcommittee members were selected to ensure that the subcommittee's membership consists of a wide range of perspectives and interests, including representation from industry, public interest groups, and academia.

Name	Entity Representing	Position Title
Robert 'Bob' Litterman (Chairman)	Kepos Capital	Chairman of the Risk Committee and Founding Partner
Clark E. Anderson	Morgan Stanley	Managing Director
Nathaniel Bullard	BloombergNEF	Chief Content Officer
Ben Caldecott	Special Government Employee	Director, Oxford Sustainable Finance Programme & Associate Professor Smith School of Enterprise and the Environment, University of Oxford
Martina L. Cheung	S&P Global	President, S&P Global Market Intelligence
John T. Colas	Marsh & McLennan Companies	Vice Chairman, Oliver Wyman Financial Services America
Robert Coviello	Bunge	Senior Vice President, Sustainability and Government Affairs
Peter W. Davidson	Aligned Climate Capital	Co-Founder and Chief Executive Officer

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Name	Entity Representing	Position Title
Jeffrey S. Dukes	Special Government Employee	Director, Purdue Climate Change Research Center; Professor of Forestry and Natural Resources; Professor of Biological Sciences; Belcher Chair for Environmental Sustainability
Hervé P. Duteil	BNP Paribas	Chief Sustainability Officer
Athena Eastwood	Dairy Farmers of America	Outside Counsel
Eliza H. Eubank	Citigroup	Managing Director and Global Head of Environmental and Social Risk Management
Naty Figueroa	BP	Global Environmental Products Commercial Manager
Christopher J. Goolgasian	Wellington Management	Managing Director; Director, Climate Research; and Portfolio Manager
John Hartmann	Cargill	Global Sustainability Lead, Cargill Agricultural Supply Chain and Global Edible Oils
Dave Jones	The Nature Conservancy	Senior Director of Environmental Risk
Jesse M. Keenan (Editor)	Special Government Employee	Associate Professor of Real Estate, School of Architecture, Tulane University
Nathaniel Keohane	Environmental Defense Fund	Senior Vice President for Climate
Mindy Lubber	Ceres	Chief Executive Officer and President
Divya Mankikar	CalPERS	Investment Manager
Leonardo Martinez-Diaz (Editor)	World Resources Institute	Global Director of the Sustainable Finance Center
Sara Menker	Gro Intelligence	Founder and Chief Executive Officer
Stephen Moch (Associate Editor)	Special Government Employee	Graduate Student, Harvard Business School & Harvard Kennedy School

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Name	Entity Representing	Position Title
Adrienne Monley	Vanguard	Head of Investment Stewardship, Americas
Adele Morris	Special Government Employee	Senior Fellow and Policy Director, Climate and Energy Economics Project, The Brookings Institution
David Parham	Sustainability Accounting Standards Board	Director of Research – Projects
Daniel R. Paul	ConocoPhillips	Commercial Manager of Risk, Regulatory Affairs, Market Analysis & Business Development
Rene Ramos	JPMorgan Chase	Executive Director, Climate Risk Executive, Global Environment and Social Risk Management
Armin Sandhoevel	Allianz Global Investors	Chief Investment Officer, Infrastructure Equity
Truman Semans	OS-Climate	Founder and Chief Executive Officer
Betty Simkins	Special Government Employee	Professor of Finance and Williams Chair; Head, Department of Finance, Spears School of Business, Oklahoma State University
Johannes Stroebel	Special Government Employee	David S. Loeb Professor of Finance and the Boxer Faculty Fellow at the New York University Stern School of Business
David S. Vogel	Voloridge Investment Management	Founder and Chief Executive Officer
Julie Winkler	CME Group	Chief Commercial Officer

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