Climate Change and the Financial Sector: A Time of Risk and Opportunity

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Introduction

Climate change is having a negative impact on economies around the world. As warming air and sea temperatures increase the frequency and intensity of extreme weather events, the potential costs of these impacts rise. In the United States, there is a greater than ninety percent chance that severe weather will cause

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at least $1 billion in insured losses each year,[1] and potentially far more in uninsured losses—costs that U.S. taxpayers bear via federally funded disaster-assistance programs.[2] In 2016 alone, there were fifteen "weather and climate disaster events" that each caused $1 billion or more in overall economic losses.[3] In addition to extreme and acute climatic events, we are also seeing chronic, slower-moving changes that impact economic activity, such as shifts in water availability or rainfall patterns that affect agricultural production.[4] Climate change is too great a problem to be addressed only by policymakers; rather, it is a matter that must be managed by all parts of society, including consumers, businesses, and the financial sector.

International efforts to address climate change advanced significantly in December 2015 when 195 countries signed the Paris Agreement.[5] This signaled a collective commitment to aim to reduce greenhouse gas ("GHG") emissions sufficiently to limit global warming to two degrees Celsius.[6] While the Paris Agreement was celebrated as a political milestone, efforts to ensure that the implications of climate change are integrated by the financial sector—particularly the many trillions of dollars managed by bankers, investors, and asset managers—continue. The importance of integrating climate considerations into financial decisionmaking is evident from the reality that, to a large degree, those actors have the potential to either make the problem worse (for example, by continuing to increase fossil-fuel exploration, production, and utilization) or support solutions (for example, by investing in clean energy and climate resilience). Despite recent political changes around the world that threaten to undermine climate policies,[7] the momentum behind opportunities to make climate-smart investments has increased exponentially over the last decade, and—perhaps most importantly—awareness of climate risk is also rising rapidly.

Fortunately, the financial sector is waking up to climate change—first and foremost because, as recent experience shows, the impact of extreme weather events can have devastating financial and human impacts. Awareness of "climate

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1. OFFICE OF MGMT. & BUDGET, EXEC. OFFICE OF THE PRESIDENT, STANDARDS AND FINANCE TO SUPPORT COMMUNITY RESILIENCE 5 (2016), https://obamawhitehouse.archives.gov/sites/default/files/omb/reports/omb_resilience_finance_report.pdf.

2. *See, e.g.*, *id.* at 17.

3. Adam Smith et al., *U.S. Billion-Dollar Weather & Climate Disasters: 1980–2016*, NOAA NAT'L CTRS. FOR ENVTL. INFO., https://www.ncdc.noaa.gov/billions/events.pdf (last visited Mar. 17, 2017).

4. *See infra* sections I.A.1 and II.A.

5. Press Release, U.N. Climate Change Secretariat, Historic Paris Agreement on Climate Change; 195 Nations Set Path to Keep Temperature Rise Well Below 2 Degrees Celsius (Dec. 12, 2015), http://unfccc.int/files/press/press_releases_advisories/application/pdf/pr20151112_cop21_final.pdf.

6. *Id.*

7. *See, e.g.*, Coral Davenport, *Climate Change and the Incoming Trump Government*, N.Y. TIMES (Dec. 19, 2016), http://www.nytimes.com/interactive/2016/12/19/us/politics/climate-change-trump-administration.html; Juliet Eilperin, *Trump Says 'Nobody Really Knows' if Climate Change is Real*, WASH. POST (Dec. 11, 2016), https://www.washingtonpost.com/news/energy-environment/wp/2016/12/11/trump-says-nobody-really-knows-if-climate-change-is-real.

risk" as a financial risk is growing in the financial sector and there are initial efforts to incorporate these considerations into decisionmaking by banks, investors, and long-term asset holders. These shifts in the policy landscape (as evidenced most clearly by the Paris Agreement, but also by green policy initiatives in some countries such as China, Brazil, Bangladesh, and the United Kingdom) signify not just political consensus, but also growing momentum for action at the nexus of climate change policy and the finance, including via incentives, carbon pricing or other policy measures.

Yet, outside the halls of climate conferences, the awareness about climate issues, risks, and opportunities has yet to become mainstream for most financial actors. There is emerging awareness within the financial sector that climate change is creating enormous business opportunities—both in the form of investments that reduce GHG emissions, and more importantly, through measures, tools, services, and investments that enhance climate resilience. Supportive government policies can accelerate the recognition of these risks and opportunities, and in turn demonstrate that actions to address climate change can be profitable, ideally contributing to a virtuous cycle of investments that support climate policies, and vice versa. Furthermore, these opportunities not only help to mitigate financial risks, but also address risks to the wider economy. As consideration of climate risks becomes mainstream in the financial sector, the integration of these risks will become, simply, good business practice throughout the economy.

I. GLOBAL AMBITION AND THE 2015 PARIS AGREEMENT

A. BACKGROUND

1. The Science of Human-Induced Climate Change is Unequivocal

As discussed below, the scope and impact of policies necessary to effectively address climate change are significant—even transformational. Thus, it is not surprising that fossil fuel and other economic interests likely to be adversely affected have invested heavily in challenging climate science.[8] In fact, the international scientific consensus process behind the conclusion that human activities are influencing the climate may be unprecedented for any scientific issue. To achieve this consensus, the Intergovernmental Panel on Climate Change ("IPCC") was initiated in 1988 by several international organizations to engage the widest possible participation of scientists in preparing periodic reviews of the status of climate science.[9] Five such reports have been produced, the most recent

8. Douglas Fischer, *Dark Money Funds Climate Change Denial Effort*, SCI. AM. (Dec. 23, 2013), http://www.scientificamerican.com/article/dark-money-funds-climate-change-denial-effort/.

9. *Organization*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, http://www.ipcc.ch/organization/organization.shtml (last visited Nov. 23, 2016).

in 2013–2014, each typically involving thousands of scientists from over 100 countries.[10] The most recent summary report[11] includes the following conclusions:

> Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems.
>
> . . .
>
> Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen.
>
> . . .
>
> Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks.

While less formal than the IPCC, other influential groups of scientists have expressed similar views often accompanied by dire warnings. In 2016, 375 members of the National Academy of Sciences—including thirty Nobel Laureates—published an open letter warning of the dangers of climate change that stated in part:

> Human-caused climate change is not a belief, a hoax, or a conspiracy. It is a physical reality. Fossil fuels powered the Industrial Revolution. But the burning of oil, coal, and gas also caused most of the historical increase in atmospheric levels of heat-trapping greenhouse gases. This increase in greenhouse gases is changing Earth's climate.
>
> Our fingerprints on the climate system are visible everywhere. They are seen in warming of the oceans, the land surface, and the lower atmosphere. They are identifiable in sea level rise, altered rainfall patterns, retreat of Arctic sea ice, ocean acidification, and many other aspects of the climate system. Human-caused climate change is not something far removed from our day-to-day experience, affecting only the remote Arctic. It is present here and now, in our own country, in our own states, and in our own communities.[12]

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10. *Structure*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, https://www.ipcc.ch/organization/organization_structure.shtml (last visited Nov. 23, 2016).

11. *Climate Change 2014: Synthesis Report Summary for Policymakers*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 2, 8 (2014) [hereinafter *IPCC Summary 2014*], https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf.

12. An Open Letter Regarding Climate Change from Concerned Members of the U.S. National Academy of Sciences (Sept. 20, 2016), http://responsiblescientists.org/.

2. The UNFCCC

The U.N. Framework Convention on Climate Change ("UNFCCC") was adopted at the Rio Earth Summit in 1992.[13] President George H.W. Bush was among more than 100 heads of state in Rio to sign the agreement—a "framework" without targets or timetables for reductions in GHG emissions.[14] The UNFCCC did, however, make a strong statement about the seriousness of the problem: "The ultimate objective of this convention . . . is to achieve . . . stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[15] Developed countries responsible for most GHG emissions accepted the obligation to act first; a list of those countries was included in Annex I of the UNFCCC.[16] Developed countries also agreed to provide poorer nations with financial support and technologies for climate change actions.[17] Industrialized countries also agreed to submit an annual inventory of their GHG emissions and to report regularly on their climate change policies.[18]

The parties meet every year in an annual Conference of the Parties ("COP").[19] The importance of negotiating targets and timetables for GHG emission reductions was recognized almost immediately with the initial such agreement, the Kyoto Protocol, adopted at COP3 in 1997.[20] The developed countries accepted specific emission reduction targets with the aim of an overall reduction of five percent relative to 1990 levels by 2008–2012.[21] However, the U.S. Senate rejected the treaty and it was generally considered a failure—although the five percent reduction was achieved.[22] The next major effort at an international

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13. Stephanie Meakin, *The Rio Earth Summit: Summary of the United Nations Conference on Environment and Development*, PARLIAMENT OF CANADA, LIBR. OF PARLIAMENT—SCI. & TECH. DIV. (Nov. 1992), http://publications.gc.ca/Collection-R/LoPBdP/BP/bp317-e.htm.

14. *Id.*; *see also U.N. Briefing Papers: Earth Summit*, U.N. DEP'T OF PUB. INFO. (May 23, 1997), http://www.un.org/geninfo/bp/enviro.html.

15. U.N. Framework Convention on Climate Change, art. 2, May 9, 1992, S. TREATY DOC No. 102-38, 1771 U.N.T.S. 107 [hereinafter UNFCCC text], http://unfccc.int/files/essential_background/convention/background/application/pdf/convention_text_with_annexes_english_for_posting.pdf.

16. *Id.* art. 4, ¶ 2(a).

17. *Id.* art. 4, ¶ 3.

18. *First Steps to a Safer Future: Introducing the United Nations Framework Convention on Climate Change*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, http://unfccc.int/essential_background/convention/items/6036.php (last visited Nov. 23, 2016). This inventory is based on consistent metrics developed in cooperation with the IPCC, and becomes the basis for estimating national contributions to global GHG emissions, which in turn is the basis for entry into force of subsequent revisions—including the Paris Agreement—as discussed below. *See infra* section 1.A.3.

19. UNFCCC text, *supra* note 15, art. 7, ¶ 4.

20. *Status of Ratification of the Kyoto Protocol*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php (last visited Oct. 22, 2016).

21. Ed King, *Kyoto Protocol: 10 Years of the World's First Climate Change Treaty*, CLIMATE HOME (Feb. 16, 2015, 2:37 PM), http://www.climatechangenews.com/2015/02/16/kyoto-protocol-10-years-of-the-worlds-first-climate-change-treaty/.

22. *Id.*

agreement to reduce emissions was the Copenhagen Accord, signed at COP15 in 2009.[23] This agreement failed to achieve consensus but included several key elements of the future Paris Agreement: a goal of limiting warming to two degrees Celsius, a commitment to mobilize $100 billion a year by 2020 to assist developing countries with climate actions, and the creation of a new Green Climate Fund as an entity to oversee climate finance.[24]

One feature of the UNFCCC is a requirement for submission of a formal instrument of ratification by some minimum number of countries before the Convention comes into force—which was "on the ninetieth day after the date of deposit of the fiftieth instrument of ratification, acceptance, approval or accession."[25] Thus the Convention had 166 signatures as of June 19, 1993 but did not come into force until March 21, 1994.[26] A similar process was included in the Paris Agreement, which provides that it "shall enter into force on the thirtieth day after the date on which at least 55 parties to the Convention accounting in total for at least an estimated 55 per cent of the total global greenhouse gas emissions have deposited their instruments of ratification, acceptance, approval or accession."[27] This requirement was satisfied on October 5, 2016, as discussed below.

3. Paris Agreement

The Paris Agreement, signed in Paris by 195 countries attending the UNFCCC COP21 in December 2015, was a high point for international efforts to address climate change.[28] The parties agreed to aim collectively to reduce their GHG emissions sufficiently to limit global warming to two degrees Celsius above pre-industrial levels[29]—a goal that would require a dramatic shift from current trends in energy use and other economic activities in less than two decades. The desirability of a much more ambitious goal, to limit warming to 1.5 degrees Celsius, was also recognized although not formally adopted as a goal.[30]

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23. Elliot Diringer et al., *Summary: Copenhagen Climate Summit*, CTR. FOR CLIMATE & ENERGY SOL. (Dec. 21, 2009), http://www.c2es.org/international/negotiations/cop-15/summary.

24. *Id.* ("Venezuela, Sudan, Nicaragua, Bolivia and a few others fought to block the leaders' agreement because most parties were outside the room when it was negotiated. Venezuela declared the agreement a 'coup d'etat against the United Nations,' and Sudan likened its effects on poor nations to those of the Holocaust, prompting a round of angry demands that the comment be withdrawn. Though the accord ultimately won formal recognition despite the lack of full consensus, the episode left many privately questioning the prospects for significant further progress within a fully global, procedurally bound U.N. process.").

25. UNFCCC text, *supra* note 15, art. 23, ¶¶ 1–2.

26. *Status of Ratification of the Convention*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, http://unfccc.int/essential_background/convention/status_of_ratification/items/2631.php (last visited Nov. 23, 2016).

27. Paris Agreement to the United Nations Framework Convention on Climate Change, art. 2.1, ¶ 1, Dec. 12, 2015, T.I.A.S. No. 16-1104 [hereinafter Paris Agreement].

28. U.N. Climate Change Secretariat, *supra* note 5.

29. Paris Agreement, *supra* note 27, art. 2, ¶ 1.

30. *Id.* (aiming to "*pursu*[*e*] *efforts* to limit the temperature increase to 1.5 °C above pre-industrial levels" as opposed to committing directly to achieving a 1.5 °C goal) (emphasis added). At the urging of the most

The outcome builds on several key agreements reached in preceding years, and a "bottom-up" process in which countries defined individual emission reduction goals through Intended Nationally Determined Contributions ("INDCs").[31] One of the key agreements critical to the success of Paris was a commitment by donor countries to increase their financial support of developing country climate actions to "mobilize" $100 billion a year by 2020.[32]

While deserving of celebration, the Paris Agreement also was widely seen as one step in a long journey; the measures collectively proposed by nations were inadequate to reach the two-degree goal. Currently, the collective ambition of the INDCs is estimated to limit warming to between 2.7 degrees and 4.6 degrees Celsius.[33] The level of collective ambition must be substantially increased, and a ratchet mechanism is embedded in the Paris Agreement for countries to increase their ambition over time.[34] Overall, the International Energy Agency ("IEA") predicts that the energy mix will need to change substantially by 2050 to meet the two-degree scenario, with fossil fuel sources across all sectors (including power generation, transportation, and buildings) comprising only forty-five percent, compared to more than eighty percent globally today.[35] A transition of this magnitude suggests a need for massive investment.

Given this background, many noted that the achievements of the Paris Agreement were not the end of the road, but just the beginning.[36] Indeed, 2016 was meant to be the start of a more coordinated, orchestrated effort by all stakeholders—public, private, businesses, the finance community, and countries—to make significant strides to address climate change. Indeed, each of these communities delivered their own somewhat impressive commitments during the

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vulnerable small island states, the parties recognized the significant gap between countries' mitigation pledges and the actions required to actually reach the 2 °C goal. *See* U.N. Framework Convention on Climate Change, *Report of the Conference of the Parties on its Twenty-First Session, Held in Paris from 30 November to 13 December 2015*, U.N. Doc. FCCC/CP/2015/10/Add.1, Decision 1/CP.21 (Jan. 29, 2016) [hereinafter Decision 1/CP.21], http://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf. The decision document (which is not formally part of the Paris Agreement) also "[i]nvites the Intergovernmental Panel on Climate Change to provide a special report in 2018 on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways." *Id.* § II, ¶ 21. For extensive insight into the origins and implications of a 1.5°C temperature limit, including its technical feasibility, see *1.5°C Temperature Limit—Key Facts*, CLIMATE ANALYTICS, http://climateanalytics.org/hot-topics/1-5c-key-facts.html (last visited Nov. 23, 2016).

31. Decision 1/CP.21, *supra* note 30, § II.

32. *Id.* § IV, ¶ 114.

33. *Climate Scoreboard*, CLIMATE INTERACTIVE, https://www.climateinteractive.org/programs/scoreboard/ (last visited Nov. 23, 2016).

34. Paris Agreement, *supra* note 27, art. 4.

35. *Energy Technology Perspectives 2016 Webinar*, INT'L ENERGY AGENCY (June 2, 2016), https://www.iea.org/media/etp/etp2016/ETP2016_Webinar_ALL.pdf.

36. *E.g.*, Molly Bergen, *For Critical Climate Change Action, Paris Agreement Just the Beginning*, CONSERVATION INT'L BLOG (Apr. 20, 2016), http://blog.conservation.org/2016/04/for-critical-climate-change-action-paris-agreement-just-the-beginning/; Ali Bongo Ondimba, *President of Gabon: The Paris Agreement is Just the Start of Africa's Climate Quest*, WIRED (Apr. 22, 2016, 7:00 AM), http://www.wired.com/2016/04/ratify-paris-climate-agreement/.

Paris conference. From the business community, for example, more than 450 CEOs from sixty-five countries committed to actions, such as integrating carbon pricing into investment strategies and supporting science-based emissions targets.[37] From the finance community, examples of commitments made by banks, investors and asset managers in Paris include: the Smart Risk Investing Initiative, which aims to increase the amount of climate-smart investment by the global insurance initiative to $420 billion by 2020,[38] and the Portfolio Decarbonization Coalition, which supports common practices for investors to measure and disclose the carbon intensity of their portfolios.[39]

The Paris Agreement includes a process for periodic review of national efforts with the goal of commitments to further emission reductions,[40] but, as discussed below, time is an issue as delay will increase the cost and difficulty of staying within targets for capping atmospheric concentrations of GHGs.[41]

Momentum on the policy side continues. Following the drafting of the Paris Agreement in December 2015, 175 countries made these commitments official by signing the Paris Agreement at the United Nations in April 2016.[42] The Agreement specified that it would enter into force thirty days after at least fifty-five parties to the Convention accounting for at least fifty-five percent of the total global GHG emissions had deposited their instruments of ratification, acceptance, approval, or accession.[43] This dual threshold was achieved on October 5, 2016; thus the Agreement entered into force on November 4, 2016.[44] COP22 in Marrakech concluded two weeks later with an optimistic Proclamation noting that since the Paris Agreement, "we have seen extraordinary momentum

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37. Press Release, U.N. Framework Convention on Climate Change, Global Business Community Comes to Paris with Solutions for Taking on the Climate Challenge Across the Board (Dec. 8, 2015), http://newsroom.unfccc.int/lpaa/business/lpaa-focus-on-business-global-business-community-comes-to-paris-with-solutions-for-taking-on-the-climate-challenge-across-the-board/.

38. *Smart Risk Investing Initiative*, LIMA-PARIS ACTION AGENDA, http://newsroom.unfccc.int/lpaa/private-finance/smart-risk-investing/ (last visited Nov. 1, 2016).

39. *The Portfolio Decarbonization Coalition*, U.N. ENV'T PROGRAMME—FIN. INITIATIVE, http://www.unepfi.org/fileadmin/documents/PortfolioDecarbonizationCoalition.pdf (last visited Nov. 1, 2016).

40. Paris Agreement, *supra* note 27, art. 4.

41. As Bodansky notes, among the outstanding features of the Paris Agreement:

> [I]t establishes a long-term, durable architecture, in contrast to the Copenhagen Accord, which involved one-shot pledges addressing only the period up to 2020 . . . . [T]he long-term architecture institutionalizes an iterative process, in which, every five years, parties will come back to the table to take stock of their collective progress and put forward emission reduction plans for the next five-year period . . . . [And] it sets an expectation of progressively stronger action over time.

Daniel Bodansky, *The Paris Climate Change Agreement: A New Hope?*, 110 AM. J. OF INT'L L. 288, 290 (2016).

42. Press Release, U.N. Framework Convention on Climate Change, Record Support for Advancing Paris Climate Agreement Entry into Force (Apr. 22, 2016), http://newsroom.unfccc.int/paris-agreement/closing-paris-agreement-signing-press-release/.

43. Paris Agreement, *supra* note 27, art. 21, ¶ 1.

44. *Paris Agreement—Status of Ratification*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE, http://unfccc.int/paris_agreement/items/9444.php (last visited Oct. 22, 2016). See *id.* for an up-to-date list of countries showing the status of their ratification.

on climate change worldwide, and in many multilateral fora. This momentum is irreversible—it is being driven not only by governments, but by science, business and global action of all types at all levels."[45]

The UNFCCC's financial mechanism—the Green Climate Fund ("GCF")—also achieved its initial goals, received pledges in excess of $10 billion by Paris, and began approving investments in 2015.[46] As of July 2016, the GCF has approved more than $225 million in funding and has accredited thirty-three agencies, including several national-level institutions.[47] In October 2016, the parties to the Montreal Protocol also announced an agreement to phase out hydrofluorocarbons ("HFCs")—chemicals that were developed as substitutes for ozone-damaging chlorofluorocarbons ("CFCs") but unfortunately turned out to be potent GHGs.[48] The same month, the members of the International Civil Aviation Organization ("ICAO") reached an agreement to cap emissions from international airline flights.[49]

B. EMERGING AWARENESS AMONG FINANCE ACTORS OF THE COSTS OF CLIMATE CHANGE

If momentum on the policy side has continued at a steady pace throughout 2016, it is unclear whether the same momentum continues with the financial sector. While the seriousness of climate change has been evident to scientists for decades, the financial sector is just beginning to recognize the links between climate change and its impacts to the wider economy, or more specifically the potential risks to financial returns on investment. Until recently, the financial world was arguably largely outside of the discussions and decisions made within the UNFCCC—a forum originated and still largely dominated by ministries with authority for the environment and foreign affairs. With the successes of Paris—including the enormous efforts by some organizations whose mission is to

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45. *Marrakech Action Proclamation for Our Climate and Sustainable Development*, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE (Nov. 18, 2016), http://unfccc.int/files/meetings/marrakech_nov_2016/application/pdf/marrakech_action_proclamation.pdf.

46. *See Resources Mobilized*, GREEN CLIMATE FUND, http://www.greenclimate.fund/partners/contributors/resource-mobilization (last visited Nov. 1, 2016) (status and sources of GCF financial pledges).

47. Press Release, Green Climate Fund, GCF Board Approves Projects Worth $250M and Prepares for Leadership Transition (July 1, 2016), http://www.greenclimate.fund/-/gcf-board-approves-projects-worth-250m-and-prepares-for-leadership-transition. At its October 2016 meeting, the Green Climate Fund announced that it had made its first disbursement of funds to the Acumen Fund, a project to attract investment for small and medium-sized enterprises promoting clean energy. GREEN CLIMATE FUND, REPORT ON THE FOURTEENTH MEETING OF THE BOARD, 12-14 OCTOBER 2016 8, http://www.greenclimate.fund/documents/20182/409835/GCF_B.14_18_-_Report_of_the_fourteenth_meeting_of_the_Board__12-14_October_2016.pdf/76e4ddee-24e3-40b8-89fa-79c86295bb7c.

48. Press Release, U.N. Env't Programme, Countries Agree to Curb Powerful Greenhouse Gases in Largest Climate Breakthrough Since Paris (Oct. 15, 2016), http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=27086&ArticleID=36283&l=en.

49. Press Release, International Civil Airlines Organization, Historic Agreement Reached to Mitigate International Aviation Emissions (Oct. 6, 2016), http://www.icao.int/Newsroom/Pages/Historic-agreement-reached-to-mitigate-international-aviation-emissions.aspx.

highlight the economic and financial consequences of climate change—this no longer seems to be the case.[50]

While Paris certainly catalyzed awareness among private sector and financial actors, multiple recent climate-related weather events with significant financial and economic implications have contributed to this growing awareness. While most climate-related weather events are very different in character and consequences, extreme weather demonstrates that the impacts of climate change are of a magnitude that can have lasting and widespread economic and financial implications:

Storms and floods

- In October 2016, Hurricane Matthew caused more than $15 billion in damage throughout the Caribbean and parts of the United States.[51] Despite making landfall in the United States as a minimum Category 1 storm, it brought major wind, storm surge, flash flood, and isolated tornado damage in several states—including Florida, Georgia, South Carolina, North Carolina, and Virginia—and caused significant property damage.[52] Total economic losses in the United States were anticipated to be up to $10 billion, yet losses covered by insurance were only estimated to be up to $5 billion.[53] A large portion of the inland flood loss in hard-hit North Carolina went uninsured due to low rates of National Flood Insurance Program ("NFIP") take-up.[54]
- In 2012, Superstorm Sandy caused over $40 billion in damage in New York and almost $30 billion in New Jersey,[55] and flooded most of lower Manhattan, shutting three major New York stock exchanges for two days.[56] More than 650,000 homes were destroyed or severely damaged, and more than 800,000 insurance claims were filed for home and auto damages resulting in over $3.5 billion in payments.[57]

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50. Organizations such as Ceres, *Mobilizing Companies, Investors & Policymakers to Build a Sustainable Global Economy*, CERES, https://www.ceres.org/files/in-briefs-and-one-pagers/ceres-in-brief (last visited Nov. 1, 2016); the World Business Council on Sustainable Development ("WBCSD"), *Overview*, WORLD BUSINESS COUNCIL ON SUSTAINABLE DEVELOPMENT, http://www.wbcsd.org/Overview/About-us (last visited Nov. 7, 2016); and the We Mean Business coalition, *About*, WE MEAN BUSINESS, http://www.wemeanbusinesscoalition.org/about (last visited Nov. 1, 2016)—among others—have brought the issue of climate change to the forefront of the financial sector and business. The participation and engagement of these private-sector actors in Paris was unprecedented.

51. AON BENFIELD, GLOBAL CATASTROPHE RECAP—OCTOBER 2016, at 3 (2016), http://thoughtleadership.aonbenfield.com/Documents/20161109-ab-analytics-if-october-global-recap.pdf.

52. *Id.*

53. *Id.*

54. *Id.* at 4.

55. U.S. DEP'T OF COMMERCE, ECON. & STATISTICS ADMIN, OFFICE OF THE CHIEF ECONOMIST, ECONOMIC IMPACT OF HURRICANE SANDY, at vi–vii (2013), http://www.esa.doc.gov/sites/default/files/sandyfinal101713.pdf.

56. Steve Inskeep, *Hurricane Sandy Shuts Down Wall Street*, NPR (Oct. 29, 2012, 4:00 AM), http://www.npr.org/2012/10/29/163845750/hurricane-sandy-shuts-down-wall-street.

57. *Hurricane Sandy's Impact, By The Numbers (Infographic)*, HUFFINGTON POST (Oct. 29, 2013, 8:07 AM), http://www.huffingtonpost.com/2013/10/29/hurricane-sandy-impact-infographic_n_4171243.html.

- Many developing countries are very vulnerable to extreme weather events and typically have much less insurance coverage to aid the recovery. The Philippines is hit by over twenty typhoons a year.[58] Typhoon Haiyan in November 2013 had winds exceeding 170 mph, caused a wall of water 25 feet high, severely damaged or destroyed more than a million homes, and resulted in more than 6000 deaths.[59] Donor pledges for disaster relief were almost $800 million.[60]
- In 2011, Thailand was hit by numerous tropical typhoons, some merely days apart, resulting in record rainfall, mudslides, and extreme flooding that had a substantial impact on the country's burgeoning manufacturing sector.[61] Many local and international businesses were affected, including Western Digital and Honda Motor Company. Gross Domestic Product ("GDP") declined by close to nine percent in the final quarter of 2011 as a direct result of the economic damage from the floods.[62] The World Bank estimated that the total damage from the Thai floods, including financial losses arising from the impact on supply chains and manufacturing, surpassed $45 billion, making the event one of the top five costliest weather events in history.[63]

Droughts and Wildfires

- Beginning in 2011, severe drought blanketed the State of California—the world's sixth-largest economy[64]—for close to four years, culminating in water shortages and impacts to agriculture yields for some major crops.[65] In 2015, the state imposed water rationing on municipalities, consumers, and some businesses. The drought was estimated to have cost California's economy approximately $2.7 billion in 2015 alone.[66] While the water shortages and impacts to some crops—including almonds and avocados—were widely reported, the more significant economic impact on the drier land may, in fact, have come from the increased incidence of wildfires. The National Interagency Fire Center recently reported that annual "fire seasons" are getting longer due to drier conditions and that the average size of fires has

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58. *Philippines Typhoon Facts and Figures*, DISASTERS EMERGENCY COMM., http://www.dec.org.uk/articles/facts-and-figures (last visited Nov. 1, 2016).

59. *Id.*

60. *USAID Fact Sheet on Typhoon Haiyan/Yolanda in the Philippines*, U.S. AGENCY FOR INT'L DEV. (Apr. 21, 2014), http://iipdigital.usembassy.gov/st/english/texttrans/2013/11/20131112286248.html#axzz4LOFJtlVr.

61. Suttinee Yuvejwattana, *Thailand's Economy Shrinks More Than Estimated After Floods*, BLOOMBERG NEWS (Feb. 20, 2012, 11:51 PM), http://www.bloomberg.com/news/articles/2012-02-20/thai-gdp-shrinks-9-amid-floods-in-fourth-quarter-almost-twice-estimates.

62. AON BENFIELD, 2011 THAILAND FLOODS EVENT RECAP REPORT 22 (2012), http://thoughtleadership.aonbenfield.com/Documents/20120314_impact_forecasting_thailand_flood_event_recap.pdf.

63. *Id.* at 3.

64. *California Passes France as World's 6th-Largest Economy*, REUTERS (June 17, 2016, 8:45 PM), http://fortune.com/2016/06/17/california-france-6th-largest-economy/.

65. *See* RICHARD HOWITT ET AL., U.C. DAVIS CTR. FOR WATERSHED SCI., ECONOMIC ANALYSIS OF THE 2015 DROUGHT FOR CALIFORNIA AGRICULTURE (2015), https://watershed.ucdavis.edu/files/biblio/Final_Drought%20Report_08182015_Full_Report_WithAppendices.pdf.

66. *Id.* at ES-1.

doubled since the mid-1970s.[67] The result is that more fires are burning in areas where people live, putting housing and infrastructure at risk. In 2015, California saw more than $2 billion of structural losses due to fires, placing that year at one of the costliest fire seasons in California history.[68] This trend continued in 2016.[69]

- In 2010, a drought destroyed one-quarter of Russia's wheat crops (Russia is the third-largest global exporter of wheat).[70] In response, the government banned exports, causing prices to spike and leading to food riots in some developing countries.[71] Some experts believe that water scarcity and its associated impacts are at least a contributing factor in many global conflicts, including the civil war in Syria.[72]

For the most part, scientists have been hesitant to draw direct causal links between extreme weather events and climate change, although that has been changing. For Superstorm Sandy, the Thai floods, and the California drought, there seems to be agreement that climate change exacerbated the intensity—and thus the economic and financial impacts—of those weather events.[73] Research from the National Academies of Sciences in 2016 shows clear linkages between a warming planet and extreme weather, in part due to increased moisture and energy available to fuel storms.[74] Weather-related disasters are not solely limited to impacts from storms (including wind, torrential rains, and flooding), but can also include impacts from drought and fire, in part because greater warming leads

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67. *Wildland Fire Management Oversight Hearing Before the S. Comm. on Energy and Nat. Res.*, 113th Cong. 17 (2013) (statement of Doug Decker, Or. State Forester, Or. Dep't of Forestry); Jesse Roman, *The Year in Wildfire*, NAT'L FIRE PROT. ASS'N J. (Nov. 2, 2015), http://www.nfpa.org/news-and-research/publications/nfpa-journal/2015/november-december-2015/features/the-year-in-wildfire.

68. Roman, *supra* note 67.

69. *California Wildfire Updates: Fast-Moving Fire in Santa Cruz Mountains Threatens Structures*, L.A. TIMES (Sept. 27, 2016), http://www.latimes.com/local/california/la-me-updates-wildfire-season-where-are-california-s-1471880147-htmlstory.html.

70. *Global Food Shortage Fears as Russia Extends Wheat Ban*, TELEGRAPH (Sept. 3, 2010, 6:00 AM), http://www.telegraph.co.uk/news/worldnews/europe/russia/7978954/Global-food-shortage-fears-as-Russia-extends-wheat-ban.html.

71. *Id.*

72. Peter H. Gleick, *Water, Drought, Climate Change, and Conflict in Syria*, 6 WEATHER, CLIMATE, & SOC'Y 331, 331 (2014).

73. *See* Parichart Promchote et al., *The 2011 Great Flood in Thailand: Climate Diagnostics and Implications from Climate Change*, 29 J. OF CLIMATE 367 (2016); Andrew Freedman, *How Global Warming Made Hurricane Sandy Worse*, CLIMATE CENT. (Nov. 1, 2012), http://www.climatecentral.org/news/how-global-warming-made-hurricane-sandy-worse-15190; Justin Gillis, *California Drought is Made Worse by Global Warming, Scientists Say*, N.Y. TIMES (Aug. 20, 2015), http://www.nytimes.com/2015/08/21/science/climate-change-intensifies-california-drought-scientists-say.html.

74. COMM. ON EXTREME WEATHER EVENTS & CLIMATE CHANGE ATTRIBUTIONS, NAT'L ACAD. OF SCI., ATTRIBUTION OF EXTREME WEATHER EVENTS IN THE CONTEXT OF CLIMATE CHANGE 85–125 (2016) [hereinafter NAS EXTREME WEATHER]; *see also* Graham Readfearn, *Was That Climate Change? Scientists are Getting Faster at Linking Extreme Weather to Warming*, THE GUARDIAN (Sept. 14, 2016, 5:37 PM), https://www.theguardian.com/environment/planet-oz/2016/sep/15/was-that-climate-change-scientists-are-getting-faster-at-linking-extreme-weather-to-warming.

to higher levels of evaporation and pulls additional moisture from the earth.[75]

Climate risks are a serious issue for everyone, from consumers and homeowners to businesses and policymakers.[76] To date, the impacts of many climate risks have been borne by public disaster relief, and extreme "tail risk" weather events were rare.[77] However, should the frequency of these events increase, the consequences of "tail risk" or "black swan" events brought about by climate change will not be just a public burden, but also one borne by homeowners, asset owners, financiers, and the private sector at large. Everyone will be required to prepare for and manage such risks.

For policymakers, managing climate risk is not just a matter of preparing for disasters, but also understanding how to better integrate resilience into the built environment and how climate risk can impact the soundness of other economic systems, including the financial system. Long-term resilience in physical infrastructure will likely require upfront capital investments in order to realize future savings in the form of reduced losses, lower insurance costs, and enhanced market value;[78] it also has the potential to create jobs. It is in policymakers' interest to ensure that the financial sector—including the insurance sector—integrates climate considerations to promote soundness throughout the financial system, minimizes the drain on fiscal budgets in times of disasters, and ensures that resilience is not just a matter of physical retrofitting, but also of good risk management.

The financial sector stands at the heart of climate risk, for two reasons: First, every actor in the financial ecosystem is fundamentally a risk manager, regardless of their appetite for risk (which may vary among them). Second, from the understanding of risk—in a real financial sense—will come opportunity. These opportunities are already becoming evident.

Climate risk is not difficult to identify in general terms, particularly as it relates to acute events, such as extreme weather. Still, it is perhaps one of the most challenging risks to assess and quantify, let alone manage. This Article discusses those challenges, starting with the issues of definitions, data, and analytics, and explores recent efforts to bring the topic of climate risk more into the mainstream of finance. Finally, this Article will explore some of the ways in which understanding climate risk in all its dimensions provides opportunities, not just for managing risks, but also for practical ways to drive sustainable investments and

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75. NAS EXTREME WEATHER, *supra* note 74.

76. "Climate Risk" is a term being used more frequently by policymakers, development professionals, and investors. In general, "climate risk" results from changes in climate that impact natural and human systems, as well as changes in temperatures that lead to changes in precipitation, water availability, agriculture productivity as a result of the changing climate, and in which areas are prone to vector-borne diseases.

77. A "tail risk" event is one that is possible but very unlikely—the "tail" being an extended area of low probability at the end of a distribution curve. *See* Simon Constable, *What is Tail Risk?*, WALL ST. J. (Sept. 9, 2015, 12:01 AM), http://www.wsj.com/articles/what-is-tail-risk-1441766937.

78. OFFICE OF MGMT. & BUDGET, *supra* note 1, at 5.

help transform our economy, and ultimately help accelerate the pace at which we collectively meet the global objective to keep warming below two degrees, staving off drastic consequences for future generations.

II. CLIMATE RISKS

A. CLIMATE RISK AS ECONOMIC RISK

First and foremost, climate change poses risks to the economy at large. The economic impacts of extreme weather are real and calculable, as clearly evidenced by many of examples cited in this Article, as well as events making news on a regular basis. For example, in August 2016, a two-day deluge of rain caused severe flooding in Baton Rouge, Louisiana, and resulted in 100,000 homes damaged or destroyed, and close to $10 billion in economic losses, according to major insurers.[79]

Extreme weather—such as floods, storms, droughts, and fires—have always occurred, but their intensity and possibly their frequency are expected to increase with climate change.[80] As the number of these types of events has grown, so has research on the potential economic costs of the impacts of climate change, as well as efforts to construct adaption measures for responding to these changes. There has also been an increase in research on the attribution of extreme weather events to climate change, particularly on how climate change affects the frequency and intensity of such events.[81] This research can provide valuable information to many people, including city and emergency planners, policymakers at all levels of government, individual businesses, and the private sector at large. Over the last decade, the number of attribution studies has increased along with interest in the topic; as more research is delivered, it should help provide insights and greater confidence to the large number of risk calculations required to understand climate risk.[82]

This research also helps form the basis of an ongoing—and often vibrant—discussion around opportunities to transition away from fossil sources of energy

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79. AON BENFIELD, GLOBAL CATASTROPHE RECAP—AUGUST 2016, at 4 (2016), http://thoughtleadership.aonbenfield.com/Documents/20160908-ab-analytics-if-august-global-recap.pdf.

80. NAS EXTREME WEATHER, *supra* note 74, at 40.

81. Since 2012, the World Bank Group has been publishing research on the economic costs of climate change for developing and emerging markets through its series *Turn Down the Heat*. *See Series: Turn Down the Heat*, WORLD BANK, http://www.worldbank.org/en/topic/climatechange/publication/turn-down-the-heat (last visited Oct. 29, 2016). Since 2014, the Risky Business Project from the Paulson Institute has been publishing its research on the economic costs of climate change in the United States through its series *Risky Business*. *See The Risky Business Project*, PAULSON INST., http://www.paulsoninstitute.org/economics-environment/climate-sustainable-urbanization/risky-business/ (last visited Oct. 29, 2016). The New Climate Economy project of the Global Commission on the Economy and Climate has also published several reports since 2014 on the economic costs, and the investment opportunities presented by climate change. *See About*, THE NEW CLIMATE ECON., http://newclimateeconomy.net/content/about (last visited Oct. 23, 2016).

82. NAS EXTREME WEATHER, *supra* note 74, at ix–x.

and toward a low- or zero-carbon economy, which is a critical component required to stem global warming. A related body of research focuses on how to "build in" resilience to expected changes, including reinforcing infrastructure, housing, and the built environment.

The research on the costs of climate change can be divided into two parts: (i) the estimates of the costs to transition to a low-carbon economy in line with the two-degree scenario, and (ii) the costs expected from the impacts of climate change, such as climate-related extreme weather events, or impacts on supply chains, employment, or other factors critical for economic activity.

For transition efforts, usually referred to as "mitigation," these costs are mostly associated with investments in energy and energy-related investments, including efficiency, transport, and energy consumption and production (both decentralized and utility scale). This transition may cost as much as $1 trillion per year by 2030.[83] Perhaps more importantly, the investment in built infrastructure required through 2030 is expected to be close to $90 trillion—more infrastructure than currently exists—because of growing populations, advances in technologies, and rapid urbanization expected over this period.[84] Those countries considered the "global South," which are mostly developing and emerging markets, will account for approximately two-thirds of this investment need, or approximately $4 billion per year of new infrastructure.[85] It will be critical to ensure that these investments are sustainable, which includes minimizing the embedded "climate risk" that any infrastructure will have, and ensuring that infrastructure is resilient.

The costs arising from the physical impacts of climate change can be harder to predict. These costs will be contextual, and will vary depending on the expected levels of warming, the magnitude and likelihood of climate-related weather hazards, and the severity of individual climate-related weather events. These costs will be compounded by the absorptive capacity of individuals, communities, and regions to cope with these impacts, and by the overall level of vulnerability of each community and population. The costs of the physical impacts of climate change are expected to rise—with limited exceptions, such as lower heating bills in winter—and could rise *exponentially* without proper management and planning, including efforts to reduce, mitigate or "build in" resilience to the expected future climate conditions.[86]

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83. GLOBAL COMM'N ON THE ECON. & CLIMATE, SEIZING THE GLOBAL OPPORTUNITY: PARTNERSHIPS FOR BETTER GROWTH AND A BETTER CLIMATE: THE 2015 NEW CLIMATE ECONOMY REPORT 36 (2015), http://newclimateeconomy.report/2015/wp-content/uploads/sites/3/2014/08/NCE-2015_Seizing-the-Global-Opportunity_web.pdf.

84. GLOBAL COMM'N ON THE ECON. & CLIMATE, THE SUSTAINABLE INFRASTRUCTURE IMPERATIVE: FINANCING FOR BETTER GROWTH AND DEVELOPMENT: THE 2016 NEW CLIMATE ECONOMY REPORT 10 (2016), http://newclimateeconomy.report/2016/wp-content/uploads/sites/4/2014/08/NCE_2016Report.pdf.

85. *Id.*

86. *See, e.g.*, FRANK ACKERMAN & ELIZABETH A. STANTON, NAT. RES. DEF. COUNCIL, THE COST OF CLIMATE CHANGE: WHAT WE'LL PAY IF GLOBAL WARMING CONTINUES UNCHECKED (2008), https://www.nrdc.org/sites/default/files/cost.pdf; Maya Rhodan, *Delay Action on Climate Change 10 Years and Costs Rocket 40%: Report*,

In the abstract, it is difficult to understand what these costs mean in real dollars to the economy, including to parts of the economy beyond infrastructure. Economic assessments of climate change help to bring these costs from the abstract to the tangible, and have been undertaken for many countries, regions, sectors, and across various economic factors, including health, worker productivity, agriculture, and water.

The Paulson Institute, headed by Hank Paulson—who served as Secretary of the U.S. Treasury under President George W. Bush[87]—produces one of the more comprehensive assessments of the economic impacts of climate change in the United States. These reports, published since 2014 under the title of *Risky Business*, articulate economic consequences of rising temperatures, rising seas, and stronger storms on employment, infrastructure assets, and impacts to agriculture.[88] The *Risky Business* reports have been written for national and regional contexts. To date, one regional report has looked at the economic implications in the Southeast and Texas,[89] one covered the Midwest,[90] and one was specific to California.[91] Key findings include the following:

- A continuation of current trends would mean between $66 billion and $106 billion of U.S. coastal property will be at risk and likely below sea level by 2050.[92]
- The number of days over ninety-five degrees Fahrenheit experienced by the average American is likely to be two to three times the average of the past thirty years by the year 2050—when it will be twenty-seven to fifty days per year—and forty-five to ninety-six days per year by the end of the century.[93] Summers in California will likely be hotter than summers in Texas and Louisiana are today.[94]

TIME (July 29, 2014), http://time.com/3049465/report-not-acting-on-climate-change-could-have-serious-economic-impact/.

87. *About the Paulson Institute*, PAULSON INST., http://www.paulsoninstitute.org/about/about-overview/ (last visited Oct. 29, 2016).

88. THE RISKY BUSINESS PROJECT, A CLIMATE RISK ASSESSMENT FOR THE UNITED STATES 2 (2014) [hereinafter RISKY BUSINESS—National], http://riskybusiness.org/site/assets/uploads/2015/09/RiskyBusiness_Report_WEB_09_08_14.pdf.

89. THE RISKY BUSINESS PROJECT, COME HEAT AND HIGH WATER: CLIMATE RISK IN THE SOUTHEASTERN U.S. AND TEXAS (2015), http://riskybusiness.org/site/assets/uploads/2015/09/Climate-Risk-in-Southeast-and-Texas.pdf.

90. THE RISKY BUSINESS PROJECT, HEAT IN THE HEARTLAND: CLIMATE CHANGE AND ECONOMIC RISK IN THE MIDWEST (2015) [hereinafter RISKY BUSINESS—Midwest], http://riskybusiness.org/site/assets/uploads/2015/09/RBP-Midwest-Report-WEB-1-26-15.pdf.

91. THE RISKY BUSINESS PROJECT, FROM BOOM TO BUST? CLIMATE RISK IN THE GOLDEN STATE (2015) [hereinafter RISKY BUSINESS—California], http://riskybusiness.org/site/assets/uploads/2015/09/California-Report-WEB-3-30-15.pdf.

92. RISKY BUSINESS—National, *supra* note 88, at 4.

93. *Id.*

94. RISKY BUSINESS—California, *supra* note 91, at 3.

- U.S. agriculture is expected to be severely impacted by climate change. In the near term, barring significant adaptation efforts, counties in several states will see commodity-crop losses of up to twenty-four percent due to heat extremes.[95] States in the Southeast, lower Great Plains, and Midwest risk a fifty to seventy percent loss in average annual crop yields (corn, soy, cotton, and wheat), absent agricultural adaptation by the end of the century.[96]
- Electricity systems will have large transition costs as generation switches from heating to air conditioning, with parts of the Midwest potentially seeing rate increases as high as twenty percent by mid-century.[97] The availability of cooling water and efficiency of power generation will be an issue for some regions.[98]

Of course, economic impacts from climate change are not limited to developed countries like the United States. In 2015, a Standford and University of California study estimated that future climate change would have a significant impact on economies around the world, and concluded that if left unchecked, global incomes could decline by more than twenty percent by 2100.[99] One of the major findings of this study was that there was a relationship between temperature and economic output, and that higher temperatures could lead to lower economic growth.[100] The study estimated that, if climate change is left unmitigated, per capita levels of income would fall in seventy-seven percent of countries by 2100.[101]

Climate change is also likely to undermine global gains on development. A single natural disaster—such as Hurricane Mitch in Honduras—can set back development by several years and require massive disaster relief in order to return to previous levels of economic and social activity.[102] To assess future risks of climate change for development, the World Bank commissioned a series of studies titled *Turn Down the Heat*.[103] The reports provide detailed insights into the development risks associated with climate change. The first report (released in 2012) looks at the dangers of a world that is four degrees Celsius warmer based on the continuation of then-current trends, as well as a more optimistic scenario based on two degrees Celsius of additional warming, consistent with achieving

95. RISKY BUSINESS—Midwest, *supra* note 90, at 5.
96. RISKY BUSINESS—National, *supra* note 88, at 4.
97. RISKY BUSINESS—Midwest, *supra* note 90, at 5.
98. RISKY BUSINESS—National, *supra* note 88, at 17.
99. Marshall Burke et al., *Global Non-Linear Effect of Temperature on Economic Production*, 527 NATURE 235, 235 (2015).
100. *Id.*
101. *Id.* at 237.
102. *See generally* Econ. Comm'n for Latin Am. and the Caribbean, *Honduras: Assessment of the Damage Caused by Hurricane Mitch, 1998*, U.N. Doc. LC/MEX/L.367 (Apr. 14, 1999), http://www.cepal.org/publicaciones/xml/6/15506/L367-1-EN.pdf.
103. *See* WORLD BANK, *supra* note 81.

the Paris Agreement goals.[104] The second report (released in 2013) examines regionally specific projections for impacts on Africa, South Asia, and Southeast Asia, and reflects the need to take into account both localized differences and changes over time.[105] The third report (released in 2014) explores impacts on Latin America and the Caribbean, the Middle East and North Africa, and Eastern Europe and Central Asia.[106] A more recent World Bank report examines the implications of climate change for the poor, and concludes that unless development becomes more "climate informed" (designed to perform well under changing climate conditions so as not to create new vulnerabilities to climate impacts), climate change could result in an additional 100 million people living in extreme poverty by 2030.[107]

These reports made clear that climate change is a development issue and, thus, is a high priority for development institutions like the World Bank. As *Turn Down the Heat* notes, "[t]he consequences for development would be severe as crop yields decline, water resources shift, sea-levels rise, and the livelihoods of millions of people are put at risk."[108] World Bank President Jim Yong Kim characterized the projected impacts of climate change as having "serious consequences for development budgets, and for institutions like the World Bank Group, where our investments, support, and advice must now also build resilience and help affected populations adapt."[109]

B. CLIMATE RISK AS FINANCIAL RISK

While climate change clearly poses a risk to the broader economy, it is also apparent that climate change can affect the financial returns of investments and corporations. Climate change can impact financial returns in a variety of ways, including when critical infrastructure that is necessary to get goods to market is damaged or destroyed by extreme weather events. During the Thai floods mentioned above, the Japanese automaker Honda—which had significant manufacturing plants in Thailand—lost 150,000 cars when many of its factories

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104. WORLD BANK, TURN DOWN THE HEAT: WHY A 4°C WORLD MUST BE AVOIDED (2012), http://documents.worldbank.org/curated/en/865571468149107611/Turn-down-the-heat-why-a-4-C-warmer-world-must-be-avoided.

105. WORLD BANK, TURN DOWN THE HEAT: CLIMATE EXTREMES, REGIONAL IMPACTS, AND THE CASE FOR RESILIENCE (2013), http://documents.worldbank.org/curated/en/975911468163736818/Turn-down-the-heat-climate-extremes-regional-impacts-and-the-case-for-resilience-full-report.

106. WORLD BANK, TURN DOWN THE HEAT: CONFRONTING THE NEW CLIMATE NORMAL (2014), https://openknowledge.worldbank.org/handle/10986/20595.

107. STEPHANE HALLEGATTE ET AL., WORLD BANK, SHOCK WAVES: MANAGING THE IMPACTS OF CLIMATE CHANGE ON POVERTY 2, 17 (2016), https://openknowledge.worldbank.org/handle/10986/22787.

108. Press Release, World Bank, "New Climate Normal" Poses Severe Risks to Development—World Bank Report (Nov. 23, 2014), http://www.worldbank.org/en/news/press-release/2014/11/23/new-climate-normal-poses-severe-risks.

109. *Id.*

around the country were inundated.[110] One of Honda's plants experienced more than fifty days underwater before recovery and repair efforts could begin,[111] and it took more than 170 days to return to normal operations.[112] The overall impact to Honda's operating profits that year was approximately 1.4 billion yen, with a net profit reduction of almost sixty percent.[113] The combination of unusually high rainfall outside the monsoon season and sea-level rise in the area of the river outlet contributed to the severity of these Thai floods.[114]

A decade or two ago, efforts to quantify economic impact or financial costs of climate change primarily focused on time horizons that were decades in the future. Today, much of economic activity is already impacted by a changed climate, and future extreme weather events are foreseeable, if not predictable. Thus, the risks from climate impacts need to be integrated into risk management practices for businesses and corporations for today's conditions, as well as for the conditions of the future. However, this integration should also be part of risk-management processes among those who finance the economy, including financial institutions, banks, and investors. Finance entails transferring risk for a price and making investments that are believed to provide good returns for the risks taken. Identifying and evaluating risks is perhaps one of the key competencies of the financial system, whether entities are lending to consumers, businesses, or even countries on the basis of creditworthiness; providing working capital to start-ups on the basis of business viability (and possibly collateral); or investing in infrastructure funds or other vehicles that aggregate and spread risks so the risks to each investor's investment are not unecessarily concentrated.

While science has underscored the potential for significant change in the climate system for decades, these "climate risks" are beginning to be understood in economic and financial terms. Indeed, in the World Economic Forum's *Global Risks Report* (released in 2016), the failure to mitigate or adapt to climate change rose to the top of the list of risks most concerning to survey respondents: even higher than terrorist threats, involuntary migration issues, interstate conflict, cyber-attacks, and energy price shocks.[115] Importantly, the survey also underscored the potential of climate risk to amplify other societal and economic risks—for example, exacerbating water stress—and alter the relationship between various risks, such as water stress and interstate conflict.[116] In another

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110. Masahiko Haraguchi & Upmanu Lall, *Flood Risks and Impacts: A Case Study of Thailand's Floods in 2011 and Research Questions for Supply Chain Decision Making*, 14 INT'L J. DISASTER RISK REDUCTION 256, 261 (2015).

111. *Id.* at 260.

112. *Id.* at 261–62.

113. *Id.* at 262.

114. Promchote et al., *supra* note 73, at 376.

115. WORLD ECON. FORUM, THE GLOBAL RISKS REPORT 2016, at 6 (2016), http://www3.weforum.org/docs/Media/TheGlobalRisksReport2016.pdf.

116. *Id.* at 30.

recently published survey by Acclimatise, thirty-six percent of all climate risks scored by businesses were marked as having a "high cost" to operations, showing increased awareness among business owners about the potential risks to their business from climate change.[117]

Furthermore, in a nod to the possible implications of climate change on credit risk, Standard and Poor's ("S&P") has published several papers that underscore the impacts of extreme weather and natural disasters on sovereign credit ratings, or on the business-risk rating of some financial actors, such as insurance companies.[118] While not specific to companies per se, a September 2015 report by S&P sampled forty-eight countries for the impacts of natural catastrophes on ratings of sovereigns, and concluded that (among others) tropical storms, floods, and winter storms of a magnitude expected once every 250 years could have the potential to weaken sovereign ratings, leading to credit downgrades of up to 1.5 notches.[119] The analysis considered the vulnerability and coping capacity of countries to prepare and respond to climate-related weather disasters.[120] We know that climate change will likely make those once-in-250-year events more frequent, in some cases making them commonplace.[121] For businesses operating in these countries, this is at a minimum a signal about the potential for increased risks to their own operations and financial returns.

These surveys and research reports point to the increasing awareness that climate change and its associated risks have the potential for serious financial and economic consequences.[122] But awareness and understanding are two different things. The ability to manage climate risk requires a full understanding and capacity to quantify what those risks will mean for exposure and costs. Developing an understanding of climate risks requires unpacking how climate change impacts the wider economy, the financial sector, businesses, and consumers. This can be highly complicated, not least because climate change impacts often interact with a range of other types of risk. In some cases, climate change is considered a "first order" risk, such as the physical risks that might need to be managed as with a changing climate (e.g., sea-level rise). In other cases, climate change is considered a "second" or "third" level risk, in that it exacerbates other

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117. ACCLIMATISE, BUSINESS OPPORTUNITIES IN A CHANGING CLIMATE 14 (2015), http://www.acclimatise.uk.com/resources?resource=261.

118. Ed King, *S&P Warn Climate Change Will Hit Corporate Credit Profiles*, CLIMATE HOME (June 5, 2015, 4:10 PM), http://www.climatechangenews.com/2015/05/06/sp-warn-climate-change-will-hit-corporate-credit-profiles/.

119. STANDARD & POOR'S RATING SERVICES, STORM ALERT: NATURAL DISASTERS CAN DAMAGE SOVEREIGN CREDITWORTHINESS 2 (2015), http://unepfi.org/pdc/wp-content/uploads/StormAlert.pdf.

120. *Id.* at 4–7.

121. *Understanding the Link Between Climate Change and Extreme Weather*, ENVTL. PROT. AGENCY, https://www3.epa.gov/climatechange/science/extreme-weather.html (last updated Oct. 19, 2016).

122. The World Economic Forum Global Risks Report hypothesized that the rise of climate change concerns was due to business perceiving that insufficient action was being taken to address the risks. WORLD ECON. FORUM, *supra* note 115, at 9–11.

risks, such as regional instability due to water constraints, or impacts on global food supplies because of droughts. What is clear is that it is no longer sufficient to categorize climate risk as merely "environmental," and ignore the impacts it may have on other types of risks to an economy, to the returns on investments, or to the profits of a business. Impacts and disruptions to business can be a result of climate impacts in the supply chain, the markets where goods are sold, or where operations are based; or they may affect the costs of financial products which can help mitigate risks, such as insurance.

Whatever the reason, financial policymakers are taking action in response to the potential economic impacts of climate change. The Financial Stability Board ("FSB") is the international organization that makes recommendations to the G20 on issues that affect global financial stability.[123] In 2015, in response to urging from Bank of England Governor Mark Carney, the FSB established an industry-led Task Force on Climate-Related Financial Disclosures ("TFCD" or "the Task Force").[124] The Task Force was a recognition that policymakers and the financial industry have an interest in ensuring that the financial system is resilient to all forms of risk, and that climate risk is now of a magnitude that requires evaluation and, potentially, disclosure.[125]

The specific mandate of the TFCD was to explore the feasibility of, and develop recommendations for, voluntary disclosure mechanisms that can allow for greater information and awareness of how climate change impacts business and financial returns—underscoring the fact that more complete, comparable, and consistent information and disclosure about climate risk will promote better decisionmaking by many types of users—including investors, businesses, lenders, and policymakers.[126]

More specifically, the TCFD unpacked the definition of climate risk into three categories,[127] each of which is seen as an important aspect of financial and business-risk management:

1. *Physical Risks* that arise from climate-related weather disasters are not solely limited to impacts from storms, where climate change exacerbates wind, increases the intensity of rains, and can lead to greater flooding. Our warming planet can also lead to greater incidents of drought and fire, in part because greater warming leads to greater levels of evaporation and pulls

123. *What We Do*, FIN. STABILITY BD., http://www.fsb.org/what-we-do/ (last visited Nov. 25, 2016).

124. Press Release, Financial Stability Board, FSB to Establish Task Force on Climate-Related Financial Disclosures (Dec. 4, 2015), http://www.fsb.org/2015/12/fsb-to-establish-task-force-on-climate-related-financial-disclosures/.

125. *Id.*

126. *About the Task Force*, FSB TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES, https://www.fsb-tcfd.org/about/ (last visited Nov. 25, 2016).

127. Mark Carney, Governor of the Bank of Eng., Speech at Lloyd's of London: Breaking the Tragedy of the Horizon—Climate Change and Financial Stability (Sept. 29, 2015), http://www.bankofengland.co.uk/publications/Documents/speeches/2015/speech844.pdf.

additional moisture from the earth, leaving lands exceptionally dry—perhaps drier as the result of higher temperatures.[128] The physical risks from a warming planet are not only in the increased incidence of extreme weather, but also in impacts to crop production and yields (both negative, and in some places positive), water resources, and even employment opportunities and potential.

2. *Transition Risks* primarily relate to the ability of economies to adjust (or "transition") to future conditions in such a way that economic and financial shocks are minimized. A key aspect of transition risk is the possibility of a carbon tax or price, which can help smooth the transition and prevent "stranded assets"—primarily in fossil industries—from accumulating for investors. In particular, stranded-asset risk manifests for two major, but interconnected, actors: (i) fossil-fuel companies themselves, which must consider the forward-looking value of their business and fossil reserves, and (ii) investors and lenders with financial stakes in those businesses.[129] Policies and technological innovations both have the potential to negatively impact the value of these assets. While the estimates for the value of loss as a result of climate change will vary over time, the fossil-fuel industry remains a significant global economic driver, and the possibility of sudden shocks that undermine value in the industry is real. However, transition risks are also possible across other sectors (not just the fossil-fuel industry) and can result from technological innovation or significant policies that are enacted later in the transition and cause significant disruption.
3. *Liability Risks* refer to the increasing potential for companies to be exposed to legal liabilities as a result of corporate mismanagement of climate risks or environmental impacts of operations. This may be relevant for insurance companies, engineering firms responsible for design of infrastructure, or manufacturers of products that fail to perform in hot weather. Further, some argue that there is potential for liability risk if "those who suffer the effects of climate change seek compensation from those they hold responsible,"[130] including developing countries seeking compensation[131] from developed countries.[132]

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128. NAS EXTREME WEATHER, *supra* note 74, at 39. "Confidence in attribution [of climate change to] specific extreme events is highest for extreme heat and cold events, followed by hydrological droughts and heavy precipitation." *Id.* at 128.

129. *See* discussion *infra* section II.C.

130. Carney, *supra* note 127. In the United States, a federal judge has refused to dismiss an action for failure to address the impacts of climate change brought by the nonprofit Our Children's Trust on behalf of twenty-one plaintiffs ages nine to twenty years old. Michele Nijhuis, *The Teen-Agers Suing Over Climate Change*, THE NEW YORKER (Dec. 6, 2016), http://www.newyorker.com/tech/elements/the-teen-agers-suing-over-climate-change.

131. Compensation claims have already become an issue in climate negotiations in the form of ongoing discussions of payment for what have come to be termed "loss and damage." *See* Saleemul Huq & Roger-Mark De Souza, *Climate Compensation: How Loss and Damage Fared in the Paris Agreement*, NEW SEC. BEAT (Jan. 12, 2016), https://www.newsecuritybeat.org/2016/01/loss-damage-fared-paris-agreement/.

132. The Paris Agreement reflects a compromise between developed countries—particularly the United States—that viewed reference to any formal acceptance of liability as politically unacceptable, and developing countries, which understandably wanted open discussions about how to meet the needs of countries (especially

These definitions of climate risk are important, and they help provide a useful lexicon for beginning to categorize climate risk. Beyond the definitions, though, is the need to start understanding what climate risk means to any investment—in a tangible, quantifiable way. This involves challenging issues with respect to the complexity of data and analytics, and the ability of investors, finance, and policymakers to access this data on a granular and contextual basis.

The TFCD delivered its preliminary report in December 2016, and concluded that:

> 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.[133]

The TFCD structured its recommendations around four thematic areas: governance, strategy, risk management, and metrics and targets.[134] These areas represent core elements of how organizations operate.[135] The TFCD recommended that entities with public debt or equity disclose climate-related risks and

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small island states) that are suffering from climate impacts with limited potential for adaptation.

> A concession by developing countries on liability and compensation was reflected in the agreement's decision text, which notes that there is no possibility of claiming liability and compensation for loss and damage. This had been a requirement from the United States, which otherwise would not agree to the other elements of the overall deal . . . . Developing countries reached a major achievement, however, in the treatment of loss and damage in an article separate from the article covering adaptation. Moreover, under the Paris Agreement the Warsaw Mechanism was embedded as a permanent institution and a task force on climate change-related displacement was established within it.

Id. Another expression of developing countries' claims for climate change liability is in the courts. In the Philippines, an action has been brought against major fossil fuel companies alleging that their contribution to global GHG emissions has been responsible for climate-related damages that constitute a human rights violation. John Vidal, *World's Largest Carbon Producers Face Landmark Human Rights Case*, THE GUARDIAN (July 27, 2016, 11:11 AM), https://www.theguardian.com/environment/2016/jul/27/worlds-largest-carbon-producers-face-landmark-human-rights-case.

133. FSB TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES, RECOMMENDATIONS OF THE TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES 2 (2016), https://www.fsb-tcfd.org/wp-content/uploads/2016/12/TCFD-Recommendations-Report-A4-14-Dec-2016.pdf. Another report recently published by the U.N. Environment Programme reviewed fifteen international financial standards for their relationship to sustainable development and made a series of recommendations based on the introduction of a principle of "maximum social benefit." U.N. ENV'T PROGRAMME, A REVIEW OF INTERNATIONAL FINANCIAL STANDARDS AS THEY RELATE TO SUSTAINABLE DEVELOPMENT, (2017), http://wedocs.unep.org/bitstream/handle/20.500.11822/16806/Review_International_Financial_Standards_Sustainable_Development.pdf?sequence=1&isAllowed=y.

134. *Id.* at iv.

135. *Id.*

opportunities in their public financial filings, and that financial-sector organizations in particular—including banks, insurance companies, asset managers, and asset owners—should begin to include climate-related disclosures in their reporting.[136] The TFCD noted that reporting climate-related information (both qualitative and quantitative) in mainstream (public) financial filings can improve investors' and others' ability to appropriately assess and price climate-related risks and opportunities.[137]

C. ADDRESSING CLIMATE RISK BEGINS WITH QUANTIFYING CLIMATE RISKS

Quantifying climate risk starts with timely and relevant data. Data is the foundation for decisionmaking, the ability to take actions to mitigate climate risks, and ultimately the ability to "build in" resilience to future changes.[138] Depending on the type of climate risk (e.g., physical, transition, or liability risk), the approach to quantifying climate risk will be different. Physical risks are particularly challenging to evaluate because their timing is uncertain and their scope may vary depending on action taken in the near term.

Analysis of physical climate risks typically starts with the use of sophisticated climate models to produce localized scenarios of probable future climate changes. Useful modeling tools take well-regarded climate science and couple it with data and information unique to the specific business context. This involves looking in detail at the business to (1) identify key risk parameters for delivering the product or service and meeting customer objectives (for example, a food company would focus on inputs, production of crops, and supply chains); and (2) develop an understanding of the climate-linked aspects of the business, including its infrastructure footprints, human capital, availability of resources, and links to financial results.[139] This process results in tens of thousands of data points that enable a statistical modeling projection tool to be the basis for understanding a business's potential risk (including future risk).[140] While still evolving, these approaches can help investors and businesses identify where risks may exist in the value chain, their potential costs, and what drives them.

For transition risks, and specifically those related to stranded assets, the risk assessment is more narrowly focused on the assumption that changes in policy,

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136. *Id.* at 14.

137. *Id.*

138. *Global Temperature Data Sets: Overview & Comparison Table*, NAT'L CTR. FOR ATMOSPHERIC RESEARCH, https://climatedataguide.ucar.edu/climate-data/global-temperature-data-sets-overview-comparison-table (last modified Mar. 25, 2014).

139. *See generally* VLADIMIR STENEK ET AL., INT'L FIN. CORP., CLIMATE RISK AND BUSINESS: PRACTICAL METHODS FOR ASSESSING RISK (2010), http://www.ifc.org/wps/wcm/connect/09deed804a830d0f85e6ff551f5e606b/ClimateRisk_Business.pdf?MOD=AJPERES.

140. Stacy Swann & Alan Miller, *EMCompass Note 10: How New Data Tools Can Assess Climate Risks*, INT'L FIN. CORP. (Sept. 2016), http://www.ifc.org/wps/wcm/connect/eff61c3e-5172-46fd-8a31-defa84b9f556/Note-10-EMCompass-How-New-Data-Tools-Can-Assess-Climate-Risks.pdf?MOD=AJPERES.

consumption, and profitability will have an adverse impact on the valuation of companies in the fossil and extractives sector. Assessing the timing and pace of regulation—and the resulting drop in consumption due to substitution that could undermine these companies' value—is inherently somewhat speculative, and investors are left wondering whether and when reserves will be realized, or if they will instead be "stranded."[141] These shifts are only recently beginning, but not yet widespread across all fossil fuels. However, there has already been a case in point with the recent significant drop in coal demand and the value of coal companies. In April 2016, Peabody Energy—the oldest and largest U.S. coal company—filed for bankruptcy after global coal prices dropped, Peabody stock plummeted, and investors fled.[142] Global coal consumption was flat in 2016, but it is expected to decline in future years, in part because substitutes like gas, wind, and other renewables have become cost competitive.[143] The value of coal companies is much lower than that of oil and gas companies, and though they produce a less carbon-intensive fossil fuel than coal, they represent a much larger threat of having "stranded assets."[144] It is estimated that between sixty and eighty

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141. Discussion of stranded assets is unavoidably contentious because it is closely linked to policy decisions expected to cause a decline in share values. For a neutral assessment, see Richard Baron & David Fischer, *Divestment and Stranded Assets in the Low-Carbon Transition*, ORG. FOR ECON. CO-OPERATION & DEV. (Oct. 28, 2015), https://www.oecd.org/sd-roundtable/papersandpublications/Divestment%20and%20Stranded%20Assets%20in%20the%20Low-carbon%20Economy%2032nd%20OECD%20RTSD.pdf.

142. Chris Mooney & Steven Mufson, *How Coal Titan Peabody, the World's Largest, Fell into Bankruptcy*, WASH. POST (Apr. 13, 2016), https://www.washingtonpost.com/news/energy-environment/wp/2016/04/13/coal-titan-peabody-energy-files-for-bankruptcy; *see generally* Event Summary, U.S. Coal in the 21st Century: Markets, Bankruptcy, Finance and Law, Sabin Ctr. for Climate Change L. at Colum. L. Sch. (Sept. 8, 2016), http://web.law.columbia.edu/sites/default/files/microsites/climate-change/panel_summaries_-_us_coal_in_the_21st_century.pdf. The value of shares in U.S. coal companies jumped after the 2016 presidential election, in anticipation of supportive policies from the new administration. *See* Timothy Caha, *Coal Stocks Soar after Trump Win*, THE HILL (Nov. 9, 2016, 11:03 AM), http://thehill.com/policy/energy-environment/305209-coal-stocks-soar-after-trump-win. However, analysts question the potential for any coal revival. Tim Worstall, *It's President Trump Now, Sure Is, and Coal Mining Jobs are Still not Coming Back to Appalachia*, FORTUNE (Nov. 11, 2016, 10:08 AM), http://www.forbes.com/sites/timworstall/2016/11/11/its-president-trump-now-sure-is-and-coal-mining-jobs-are-still-not-coming-back-to-appalachia/#e35b93c2884a.

143. The extent to which the decline in coal use was due to environmental regulations versus declining gas and renewable energy prices has been debated, but some credit can be given to both. *See, e.g.*, *Short Term Energy Outlook (STEO)*, U.S. ENERGY INFO. ADMIN., 9–10 (July 12, 2016), https://www.eia.gov/forecasts/steo/archives/Jul16.pdf; *The Gradual Decline of Coal Consumption in the United States*, ELEC. CHOICE (May 6, 2016), https://www.electricchoice.com/blog/the-gradual-decline-of-coal-consumption-in-the-united-states/.

144.

> The top 100 coal and top 100 oil & gas companies have a combined value of $7.42 trillion as at February 2011. The countries with the largest greenhouse gas potential in reserves on their stock exchanges are Russia, (253 [gigaton ("Gt")] CO_2), the United States, (156.5 Gt CO_2) and the United Kingdom, (105.5 Gt CO_2). The stock exchanges of London, Sao Paulo, Moscow, Australia and Toronto all have an estimated 20–30% of their market capitalisation connected to fossil fuels.

CARBON TRACKER, UNBURNABLE CARBON—ARE THE WORLD'S FINANCIAL MARKETS CARRYING A CARBON BUBBLE? 2 (2011), http://www.carbontracker.org/wp-content/uploads/2014/09/Unburnable-Carbon-Full-rev2-1.pdf.

percent of the coal, oil, and gas reserves of publicly listed companies are "unburnable," representing a significant amount of value at risk if the world is to stay within the two-degree goal.[145]

To date, market forces have been responsible for the recent volatility in the value of fossil fuel companies, but there is also growing pressure from groups that want shareholders to sell, or divest, their shares of such companies for moral and financial reasons.[146] The moral argument is reflected in decisions by religious organizations and some educational institutions to divest from their fossil-fuel stocks because it is necessary to protect the future health of the planet and is the right thing to do.[147] The financial argument is that the seriousness of climate change will necessarily result in restrictions on fossil fuel use that directly impact the value of fossil fuel holdings (i.e., unburnable assets). This argument is particularly relevant for the large value of shares held by pension funds that are responsible for making payments many years into the future.[148] Divestment has also become a leading issue for climate activists at universities with endowments. While arguably achieving mixed results, the issue provides a basis for organizing because it targets specific institutions and decisionmaking bodies.[149] As they are gradually implemented, the risk disclosure recommendations of the TFCD may also give added ammunition to divestment advocates.

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145. CARBON TRACKER, UNBURNABLE CARBON 2013: WASTED CAPITAL AND STRANDED ASSETS 4–5 (2013), http://www.carbontracker.org/report/unburnable-carbon-wasted-capital-and-stranded-assets/.

146. Emma Howard, *A Beginner's Guide to Fossil Fuel Divestment*, THE GUARDIAN (June 23, 2015, 2:00 AM), https://www.theguardian.com/environment/2015/jun/23/a-beginners-guide-to-fossil-fuel-divestment.

147. *See, e.g.*, Michael Slezak, *Catholic Orders Take Their Lead from the Pope and Divest from Fossil Fuels*, THE GUARDIAN (June 15, 2016, 4:19 PM), https://www.theguardian.com/environment/2016/jun/16/catholic-orders-take-their-lead-from-the-pope-and-divest-from-fossil-fuels.

148. This argument depends primarily on the belief that climate change impacts will be sufficiently serious to trigger significant policies restricting use of fossil fuels, but it also depends on timing. Some critics of divestment argue that policies sufficiently aggressive to impact share values are unlikely for more than a decade, and thus need not trigger near-term divestment. Bruce M. Kahn, Portfolio Manager, Sustainable Insight Cap. Mgmt., Presentation to the Sabin Ctr. for Climate Change L. at Colum. L. Sch.: Risks and Returns of Fossil Fuel Free Investing (Nov. 14, 2014), http://web.law.columbia.edu/sites/default/files/microsites/climate-change/nov_24_divestment_event.pdf; Simon Sheikh, *Super Funds and Fossil Fuels: Scott Morrison Should Study the Facts*, THE GUARDIAN (Aug. 24, 2016, 12:30 AM), https://www.theguardian.com/commentisfree/2016/aug/24/super-funds-and-fossil-fuels-scott-morrison-should-study-the-facts.

149. Some of the largest university endowment funds, including Harvard, have rejected divestment requests on the basis that their overriding obligation is to maximize return. Michael McDonald, *Harvard Seen Forgoing $108 Million a Year Divesting Fossil Fuels*, BLOOMBERG (Sept. 4, 2015, 6:00 AM), http://www.bloomberg.com/news/articles/2015-09-04/harvard-seen-forgoing-108-million-a-year-divesting-fossil-fuels. Stanford is among the universities agreeing to divest from coal companies. *Stanford to Divest from Coal Companies*, STAN. NEWS (May 6, 2014), http://news.stanford.edu/news/2014/may/divest-coal-trustees-050714.html. Several charitable foundations—including that of the Rockefeller family, with its fortune based on oil profits—have also agreed to some level of divestment. Rupert Neate, *Rockefeller Family Charity to Withdraw all Investments in Fossil Fuel Companies*, THE GUARDIAN (Mar. 23, 2016, 5:39 PM), https://www.theguardian.com/environment/2016/mar/23/rockefeller-fund-divestment-fossil-fuel-companies-oil-coal-climate-change. Universities in the United Kingdom have been more willing to divest from fossil fuel stocks, with a quarter already making such commitments. Damian Carrington, *Fossil Fuel Divestment Soars in UK Universities*, THE GUARDIAN (Nov. 22, 2016, 9:12 AM), https://www.theguardian.com/environment/2016/nov/22/fossil-fuel-divestment-soars-in-uk-universities.

Finally, no two businesses will have the same climate risks—including transition and physical climate risks. The ability to develop tools, analytics, and risk-management services for businesses may require incorporating both the contextual elements of a business's exposure to climate change and the ways that exposure impacts a business's revenues, costs, or asset values. Otherwise, companies, investors, and other decisionmakers may be able to develop qualitative assessments, but might find it difficult to understand which elements of climate change pose a *quantifiable* risk to business, including those related to stranded assets and transition risks. For example, while much of the awareness of and planning for climate risks focuses on extreme weather events, often the slower, chronic changes such as water availability, or sea-level rise (which can increase the incidence of "nuisance flooding") can in fact be more problematic for certain businesses.[150] Indeed, each company will have a different set of operating concerns that reflect its unique position and strategy—including different environments and geographies—and will have differing abilities to manage, plan for, and mitigate such risks.[151] This is especially true in countries where insurance markets are in their nascent stages, or are non-existent.

And, of course, each company or investor's risk managers will have varying levels of tolerance for such risks, depending on their scope, scale, time horizon, and the availability of mitigation instruments—like insurance—to protect against losses. Some companies have a strategy and business model that includes taking well-managed risks, while others are far more conservative, especially when there is a potentially large impact on returns, costs, or asset values. Nonetheless, it is important to recognize that climate change risk is not uniform, but rather has the potential to emerge in a number of ways, and may indeed exacerbate other existing risks for businesses, becoming the ultimate "threat multiplier" across

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150. Nuisance flooding is flooding that leads to "public disruptions" like road closures, overwhelmed storm drains, and deterioration of critical infrastructure, such as rail and roads. Nuisance flooding is increasing in many coastal areas, in part due to rising sea levels. *See What is Nuisance Flooding?*, NAT'L OCEAN SERV., NAT'L OCEANIC & ATMOSPHERIC ADMIN., http://oceanservice.noaa.gov/facts/nuisance-flooding.html (last modified Mar. 17, 2016).

151. A number of entities exist to help companies understand their sustainability risks, including those related to climate change. The process of sustainability reporting often helps companies determine which risks are "material," and are thus useful to disclose. The Sustainability and Accounting Standards Board ("SASB") supports companies that wish to disclose sustainability issues on financial filings and provides an interactive tool underpinned by metrics to help determine how material an issue is for companies across industries and sectors. *See* Press Release, Sustainability and Accounting Standards Board, SASB Releases Robust Research and Analytics Tool (Oct. 20, 2016, 9:00 AM), http://www.prnewswire.com/news-releases/sasb-releases-robust-research-and-analytics-tool-300347955.html. In this context, SASB defines "materiality" as information that may be decision-useful for the reasonable investor. *Materiality: Why is it Important?*, SASB, http://www.sasb.org/materiality/important/ (last visited Nov. 26, 2016). Other entities that support companies' sustainability reporting—particularly related to climate risks—include CDP (formerly the Carbon Disclosure Project), *About Us*, CDP, https://www.cdp.net/en/info/about-us (last visited Nov. 26, 2016); and the Global Reporting Initiative ("GRI"), *About GRI*, GLOB. REPORTING INITIATIVE, https://www.globalreporting.org/Information/about-gri/Pages/default.aspx (last visited Nov. 26, 2016).

many aspects of operations.[152]

In the next section, we move from explaining climate change risks—both economic and financial—and their analytical challenges, to a practical discussion of how these issues are playing out within the business and financial world. A great deal of climate-relevant investment is happening, especially with respect to clean energy and the shift to low-carbon fuels, but also more recently in the recognition that climate resilience can present investment opportunities. These developments have, in many instances, been driven primarily by factors unrelated to climate change, but will benefit from and influence climate policies in the future.

III. CLIMATE-RISK OPPORTUNITIES

The economic and financial risks of climate change appear increasingly likely, but remain uncertain in several critical respects for investors making decisions—namely regarding the scope, timing, and location of those risks. In contrast, the opportunities arising from responses to climate change are, at least in part, more immediate and readily identifiable. The greatest opportunities arise from clean-energy investments that provide services critical to economic development, primarily energy-efficiency improvements and renewable-energy technologies for power generation that are increasingly economically justified, apart from their connection to climate change. However, with indicators of climate change already appearing and almost certain to become more serious (even assuming ambitious targets for GHG reductions are met), the need for investments in climate resilience will also create sizable business opportunities. With limited exceptions, these two markets—clean energy and climate resilience—will involve very different products and services and are likely to grow at different rates and in different locations. Consequently, they will be discussed as separate topics.

A. THE TRANSITION TO A LOW-CARBON ECONOMY

The fundamental reason for the uncertainty surrounding the impacts of climate change policy is the required massive shift in investment from fossil-fuel exploration, production, and distribution, to improving efficiency—using non-carbon fuels, and perhaps carbon capture, utilization, and storage ("CCUS"). There is no disputing that this transformational shift represents a substantial change in economic activity and financial investment. The requirements of a low-carbon transition are estimated to be significant. In its 2015 World Energy

152. U.S. DEP'T OF DEF., 8-6475571, NATIONAL SECURITY IMPLICATIONS OF CLIMATE-RELATED RISKS AND A CHANGING CLIMATE 8 (2015), http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf.

Outlook, the IEA outlined the efforts required to transition to a two-degree world, including: (i) significant investment in energy efficiency measures for buildings, industry, and transport; (ii) phasing coal out as an energy source; (iii) removing fossil-fuel subsidies; (iv) reducing methane leaks and emissions in oil and gas; and (v) an increase in renewable investment of up to $400 billion by 2030.[153] IEA concluded that meeting the target is possible at zero net economic cost because the possible extra costs for some measures (particularly some new technologies) would be offset by savings from others (including energy efficiency).[154]

There is also substantial evidence that the actions required to meet climate change targets could be a source of multiple economic, environmental, and other benefits. The Global Commission on the Economy and Climate[155] concluded:

> [M]any of the policy and institutional reforms needed for revitalising growth, fostering development and improving well-being are also crucial to tackle climate risk. The opportunities for such reforms are increasing, as emerging and developing economies experience rapid urbanisation and structural change, innovation reduces the cost of a low-carbon transition, and the costs of the current economic growth model become more apparent . . . . The multiple benefits of climate action include reductions in the health impacts of air pollution, in traffic congestion and accidents; lower risk of locking in stranded assets; less vulnerability to volatile fossil fuel prices and potential fuel supply disruptions; enhanced productivity of agricultural and forested lands, and associated increases in rural income; as well as the benefits of reduced climate impacts. In terms of air pollution, for example, fossil fuel-related outdoor air pollution leads to an estimated 3.7 million premature deaths globally each year, with millions more suffering from respiratory illnesses.[156]

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153. INT'L ENERGY AGENCY, ENERGY AND CLIMATE CHANGE: WORLD ENERGY OUTLOOK SPECIAL REPORT 13 (2015), https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf.

154. *See id.* at 67.

155.

> The Global Commission on the Economy and Climate is a major international initiative to examine how countries can achieve economic growth while dealing with the risks posed by climate change. Chaired by former President of Mexico Felipe Calderón, the Commission comprises former heads of government and finance ministers and leaders in the fields of economics and business.

THE NEW CLIMATE ECON., *supra* note 81. It was commissioned by Colombia, Ethiopia, Indonesia, Norway, South Korea, Sweden, and the United Kingdom as an independent initiative to report to the international community. *Id.*

156. GLOBAL COMM'N ON THE ECON. & CLIMATE, *supra* note 83, at 14–15.

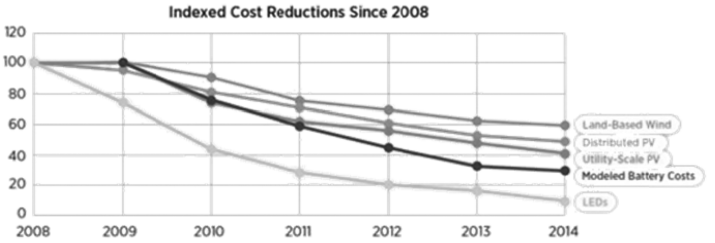

FIGURE 1: Falling Costs for Clean Energy Technologies[157]

There is increasing evidence that the investments and technologies required to stay below the two-degree target—such as wind and solar—are economically and technically feasible, and increasingly cost-competitive with other energy sources.[158] Photovoltaic ("PV") solar, wind, and battery prices continue to fall as the industry makes technological improvements, and as increasing market share brings economies of scale.[159] According to Bloomberg New Energy Finance, by 2040, energy sources that are zero-energy will contribute more than sixty percent of total installed capacity, and wind and solar will account for more than sixty-four percent of new power generation capacity added.[160] In 2016, several record-breaking PV auctions attracted bids below three cents per kilowatt-hour—including bids in Chile, Mexico, and Abu Dhabi—making solar cheaper than both coal and gas in some places.[161] These and other data points seem to indicate that clean energy is not only viable, but also will continue to be an increasingly attractive investment opportunity. Bloomberg estimates that more than $11 trillion will be invested in these areas over the next twenty-five years.[162]

1. Further Innovation in Technology

As evidenced most directly by the IEA recommendations, there is consensus that only addressing climate change through renewable energy will not keep us

157. U.S. DEP'T OF ENERGY, REVOLUTION . . . NOW: THE FUTURE ARRIVES FOR FIVE CLEAN ENERGY TECHNOLOGIES—2015 UPDATE 1 (2015), http://www.energy.gov/sites/prod/files/2015/11/f27/Revolution-Now-11132015.pdf. Figure 1, above, ("Falling Costs for Clean Energy Technologies") is from this Department of Energy report.

158. *See id.* at 2.

159. BLOOMBERG NEW ENERGY FIN., NEW ENERGY OUTLOOK 2016—EXECUTIVE SUMMARY 2–3 (2016), http://www.bloomberg.com/company/new-energy-outlook.

160. *Id.* at 2.

161. Katie Fehrenbacher, *A Jaw-Dropping World Record Solar Price was Just Bid in Abu Dhabi*, FORTUNE (Sept. 19, 2016, 12:37 PM), http://fortune.com/2016/09/19/world-record-solar-price-abu-dhabi/; *see also* Tim Buckley, *IEEFA Update: Coming Soon to a Grid Near You, Cost-Competitive Solar*, INST. FOR ENERGY ECON. & FIN. ANALYSIS (Sept 20, 2016), http://ieefa.org/cost-competitive-solar-coming-soon-grid-near/.

162. BLOOMBERG NEW ENERGY FIN., *supra* note 159, at 2.

within two degrees Celsius.[163] Another technology with short-term promise for further GHG reductions is battery technology, which is also expected to see a significant cost decline in the coming years. Joe Romm, an energy analyst and former U.S. Department of Energy official, argues that the declining cost of battery technology is primarily due to the scale-up of production, as opposed to technological advancements.[164] Recent projections are that costs will decline enough that battery-powered cars will become cheaper to drive "on an unsubsidised basis than internal combustion engine cars by the mid-2020s, even if the latter continue to improve their average mileage per gallon by 3.5% per year."[165] Battery-powered cars could reduce oil consumption by thirteen million barrels per day by 2040,[166] and further reduce power demand by doing double duty as sources of storage able to charge at night and power homes during peak periods.[167]

Another potential technology for addressing climate change that has proven controversial is CCUS: technologies which could allow continued use of fossil fuel for power generation by removing carbon dioxide ("CO_2") for utilization (e.g., for tertiary oil recovery), capture, and storage. There are many technical and economic issues associated with these technologies, which have yet to achieve full commercial status.[168] Nevertheless, some scenarios for reducing GHG emissions—including the IEA's—assume significant growth in CCUS as part of scenarios for meeting climate objectives: "[g]lobal investment to build [carbon capture and storage] grows from a few billion dollars today to about $70 billion per year in the 2020s, on average, and to $110 billion per year in the 2030s."[169]

One issue that divides advocates of climate change policy is the need for further innovation in GHG-reducing technologies. Bill Gates has called for a massive commitment to research new technologies as the only path to avoiding dangerous climate change:

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163. INT'L ENERGY AGENCY, *supra* note 153.

164. Joe Romm, *No Bill Gates, We Don't Need 'Energy Miracles' to Solve Climate Change*, THINK PROGRESS (Feb. 23, 2016), https://thinkprogress.org/no-bill-gates-we-dont-need-energy-miracles-to-solve-climate-change-60ac8fbb9e2e#.yx39z24pj.

165. Press Release, Bloomberg New Energy Fin., Electric Vehicles to be 35% of Global New Car Sales by 2040 (Feb. 25, 2016), http://about.bnef.com/press-releases/electric-vehicles-to-be-35-of-global-new-car-sales-by-2040/; *see also* FRANKFURT SCH.—U.N. COLLABORATING CTR. FOR CLIMATE & SUSTAINABLE ENERGY FIN. & BLOOMBERG NEW ENERGY FIN., GLOBAL TRENDS IN RENEWABLE ENERGY INVESTMENT 2016, at 36 (2016) [hereinafter UNEP/BNEF] ("[L]ocal storage could enable wind and solar projects to provide electricity for a larger number of hours, with less in the way of fluctuation. This could be a powerful combination at both utility-scale and in developing economy microgrids.").

166. Bloomberg New Energy Fin., *supra* note 165.

167. UNEP/BNEF, *supra* note 165, at 36.

168. Press Release, Nat'l Acad. of Sci., U.S. Should Act to Support Innovation in Increasingly Clean Electric Power Technologies and Remove Barriers to Their Adoption (Sept. 8, 2016), http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=21712.

169. INT'L ENERGY AGENCY, *supra* note 153, at 116.

> We need innovation that gives us energy that's cheaper than today's hydrocarbon energy, that has zero CO_2 emissions, and that's as reliable as today's overall energy system. And when you put all those requirements together, we need an energy miracle. That may make it seem too daunting to people, but in science, miracles are happening all the time.[170]

Gates notes the success of public support for health research and calls for a tripling of funding for energy research to $18 billion a year.[171] He has also made a personal commitment to his proposal with the creation of the Breakthrough Energy Coalition.[172] Its first announcement was the Breakthrough Energy Ventures fund, with initial funding of $1 billion and total pledges of $2 billion.[173] In contrast, Romm argues that recent declines in the cost and improvements in the performance of renewable energy technologies are already occurring, driven by public policies that have increased demand.[174] In Romm's view, cost reductions in energy technology have in practice come primarily from the learning that occurs with increased production, and not from research.[175] He fears focusing on research is unlikely to create breakthroughs in a timeframe relevant to address climate change, given the long periods typically required for energy transitions.[176]

The discussion on the role of research highlights the importance of timing when actions are taken as a variable in climate policy scenarios. Delaying action has sometimes been advocated as appropriate to allow for greater certainty and the potential for technology breakthroughs necessary to avoid overly costly investments—an argument closely akin to that of Bill Gates.[177] However, there is a growing consensus that delaying action will substantially increase the costs and technical difficulties of staying within the two degrees Celsius target.[178] Gates

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170. James Bennet, *We Need an Energy Miracle*, ATLANTIC (Nov. 2015), http://www.theatlantic.com/magazine/archive/2015/11/we-need-an-energy-miracle/407881/.

171. *Id.* In contrast, funding for health research is about $30 billion per year. *See id.*

172. Alex Nussbaum et al., *Bill Gates Leads Billionaires in $2 Billion Climate Investment*, BLOOMBERG POL. (Nov. 30, 2015, 3:03 PM), http://www.bloomberg.com/politics/articles/2015-11-30/gates-leads-billionaires-in-2-billion-climate-investment. For updates, see the website of the Breakthrough Energy Coalition: http://www.b-t.energy/coalition/.

173. Jamie Condliffe, *Bill Gates's $1 Billion Fund Will Back Radical Clean Energy Ideas*, MIT TECH. REV. (Dec. 12, 2016), https://www.technologyreview.com/s/603111/bill-gatess-1-billion-fund-will-back-radical-clean-energy-ideas/.

174. Romm, *supra* note 164.

175. *Id.*

176. *Id.*

177. *See* Isabel Galiana, *Benefits and Costs of the Climate Change Targets for the Post-2015 Development Agenda* (Copenhagen Consensus Ctr., Working Paper, Oct. 15, 2014), http://www.copenhagenconsensus.com/sites/default/files/climate_change_assessment_-_galiana_0.pdf. This paper is part of a series produced under the auspices of the Copenhagen Consensus Center, a group based on the application of economics to identify the relative costs and benefits of investment in alternative development goals (e.g., health, education, reducing pollution, etc., as well as reducing GHG emissions). For general information and links to the work of the Center, see *Post-2015 Consensus*, COPENHAGEN CONSENSUS CTR., http://www.copenhagenconsensus.com/post-2015-consensus (last visited Nov. 26, 2016).

178. *See* COUNCIL OF ECON. ADVISERS, EXEC. OFFICE OF THE PRESIDENT, THE COST OF DELAYING ACTION TO

and Romm agree on one fundamental point: energy transitions have historically taken decades to occur, a path which is entirely inconsistent with climate goals.[179]

B. THE EMERGING RESILIENCE MARKET

Becoming resilient to climate change impacts is part of the process of adapting to a warming planet, but unlike the efforts described above, which are mostly about energy production and consumption, becoming resilient will require new ways of thinking about all infrastructure, not just energy. Investments in resilience can and will take many forms, and are likely to enhance the value of assets, result in decreased costs through reduced insurance premiums and, in some cases, allow for parallel energy-efficiency measures as resilience investments are made. Many investments to reduce GHG emissions—such as renewable-energy systems and energy-efficiency improvements—will have short-term and readily quantifiable economic benefits as they provide immediate financial services in addition to their contribution to climate targets. Resilience investments can complement and augment these measures providing even more economic—and financial—benefits.

Some measures to promote climate resilience, such as modest changes in building design and construction, and incorporating resilience measures into infrastructure, are already justified by reduced risks and sometimes-reduced insurance costs. Countries like Bangladesh and the Philippines that are frequently exposed to severe storms are also incorporating the longer-term risks of climate change in their disaster planning.[180] However, uncertainties about projected impacts can impede adaptation planning and implementation.[181] Though the impacts of climate change are expected to increase, such changes will not be uniform across countries.[182]

STEM CLIMATE CHANGE (2014), https://obamawhitehouse.archives.gov/sites/default/files/docs/the_cost_of_delaying_action_to_stem_climate_change.pdf.

179.

> Transformational change in the energy sector can be a very long process, reflecting the need to reconfigure both the supply infrastructure and end-use energy equipment, while conforming to consumer preferences. For example, it took 60 years to move from the first commercial production of oil to its capturing 10% of the primary energy mix and 50 years before the volume of liquefied natural gas (LNG) reached 30% of global gas trade. For emerging technologies, policies to create initial markets must run alongside research and development programs, far ahead of the widespread deployment of the technologies, and draw on competitive market forces where possible, paving the way for exponential growth.

INT'L ENERGY AGENCY, *supra* note 153, at 107.

180. Saleemul Huq, *Fifteen Years of Climate Change Adaptation Planning*, DAILY STAR (July 17, 2016, 12:00 AM), http://www.thedailystar.net/op-ed/fifteen-years-climate-change-adaptation-planning-1254658.

181. *IPCC Summary 2014*, *supra* note 11, at 19.

182. *Id.* at 10–13.

While some suggest that there is potential profit from anticipating the fall in value of specific assets—for example, by divesting from fossil investments or shorting properties in low-lying coastal areas that are projected to flood due to sea-level rise and more severe storms[183]—there are several opportunities for businesses and investors to make proactive investments that will allow us to become more resilient to climate change. These opportunities include the built environment, and products and services that enhance climate resilience. We discuss four broad categories:

1. Climate Data, Information, and Analytical Services

As discussed above, many businesses have an initial need for locally specific climate-risk information. At a national and regional level, this includes the provision of basic weather information and early warnings of extreme events: information we take for granted in the developed world, but is often unreliable or unavailable in developing countries.[184] A general awareness that climate change is expected in coming decades will not mean much for most business operations, which require much more localized and granular information. For example, businesses or investors may need to understand storm intensity and sea-level rise for ports critical to getting their goods to market. They may need to understand heat extremes for farming and construction projects that depend on outdoor labor, or they may need to know information about rain intensity and frequency for investments in agriculture or hydropower.[185] The analytical challenges from the perspective of an individual business can be considerable, as short-term, localized forecasts of climate change are very imprecise for many parts of the world,[186] and there may be corporate vulnerability at multiple points in a value chain. For example, an agricultural processor may be at risk from the spread of malarial mosquitos, and a port may have to shut down if flooding interferes with trucking routes that load and offload goods.[187]

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183. This possibility is among the "opportunities" discussed in *Windfall*, by McKenzie Funk. *See* Dave Davies, *Entrepreneurs Looking For 'Windfall' Cash in on Climate Change*, NAT'L PUB. RADIO (Jan. 28, 2014, 1:57 PM), http://www.npr.org/2014/01/28/267082833/entrepreneurs-looking-for-windfall-cash-in-on-climate-change (interview with author McKenzie Funk). Betting on the fall in the value of mortgage-backed securities is analogous. *See* MICHAEL LEWIS, THE BIG SHORT: INSIDE THE DOOMSDAY MACHINE (2011).

184. Peter J. Webster, *Improve Weather Forecasts for the Developing World*, 493 NATURE 17, 18 (2013), http://webster.eas.gatech.edu/Papers/Webster2013a.pdf.

185. The International Finance Corporation ("IFC") has supported and published several illustrative case studies done in cooperation with investees in different sectors and geographies. *See, e.g.*, sources cited *infra* note 199.

186. Rasmus Benestad, *Downscaling Climate Information*, OXFORD RES. ENCYC. OF CLIMATE SCI. (July 2016), http://climatescience.oxfordre.com/view/10.1093/acrefore/9780190228620.001.0001/acrefore-9780190228620-e-27.

187. VLADIMIR STENEK & RICHENDA CONNELL, CLIMATE RISK AND BUSINESS: GHANA PALM OIL DEVELOPMENT COMPANY 29 (2011), http://www.ifc.org/wps/wcm/connect/2d9640804a5202f48bc49faa52ef3b86/IFC+Climate+Risk-+GOPDC+-+exec+summary.pdf?MOD=AJPERES; VLADIMIR STENEK ET AL., CLIMATE RISK AND

Having good climate data and analytics will be the precursor and foundation of any risk mitigation strategy, whether it involves "building-in" resilience measures to physical assets, or understanding weaknesses in supply chains and planning for redundancies. Specialized firms offering climate-risk information and analytical services have emerged in recent years to address this need, and no doubt more will develop as climate events increase the demand for climate analysis.[188] One notable and highly publicized example is the Climate Corporation, which uses soil sensors and weather modeling to enable farmers to substantially increase their yields, thus helping to address some of the risks associated with changing weather.[189] The company was purchased by Monsanto, a major supplier of agricultural inputs to farmers, for over $1 billion.[190]

2. Enhancing the Resilience of Infrastructure

Perhaps the most obvious and visible opportunity for business and investors is in the physical-infrastructure investments required to improve resilience, including those that enhance resilience to extreme weather events and sea-level rise. This includes a wide range of measures, from "no regrets" or "low regrets" measures, such as changes in building design and construction that offer substantially increased resilience for no or very low cost, to major investments in sea walls and other protective measures, sometimes with immediate offsetting benefits (e.g., reductions in insurance premiums). Typical examples of the former are wind-resistant construction designs in areas prone to hurricanes, and fire-resistant roofing materials in areas subject to wildfires. If incorporated at the time of construction, the additional costs can be minimal.[191] In some jurisdictions,

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BUSINESS: TERMINAL MARÍTIMO MUELLES EL BOSQUE 12 (2011), http://www.ifc.org/wps/wcm/connect/98f63a804a830f878649ff551f5e606b/ClimateRisk_Ports_Colombia_Full.pdf?MOD=AJPERES.

188. Examples include: FOUR TWENTY SEVEN, http://427mt.com (last visited Nov. 6, 2016) ("We believe resilience is a journey. Our customized solutions blend economic modeling with climate science to help our clients build awareness, mitigate risk, and identify new opportunities."); ACCLIMATISE, http://www.acclimatise.uk.com (last visited Nov. 6, 2016) ("We bridge the gap between the latest scientific developments and real-world decision-making, helping our clients to introduce cost-effective measures to build climate resilience into their strategies, processes and activities."); and COASTAL RISK CONSULTING, http://coastalriskconsulting.com (last visited Nov. 6, 2016) ("Coastal Risk is committed to making geospatial information accessible so everyone can prepare and protect themselves, their homes, communities and businesses from the impacts of climate risks such as storms, sea level rise and heavy rainfall.").

189. Press Release, The Climate Corp., The Climate Corporation to Create Industry's First In-Field Sensor Network to Feed its Analytics Platform and to Build First Centralized Platform for Industry-Wide Digital Ag Technology Development (Aug. 17, 2016), https://www.climate.com/static/cms/company/press-releases/climate-to-create-first-in-field-sensor-network.

190. Alexia Tsotsis, *Monsanto Buys Weather Big Data Company Climate Corporation for Around $1.1B*, TECHCRUNCH (Oct. 2, 2013), https://techcrunch.com/2013/10/02/monsanto-acquires-weather-big-data-company-climate-corporation-for-930m.

191. "A wind-resistant home costs a little more than a code-minimum home, but it can be several times stronger at resisting wind forces . . . . These building shell reinforcements typically cost less than $1000, including labor, for an average-sized home." *Design for Wind Resistance*, APA—THE ENGINEERED WOOD

there are legislated financial incentives, including grants and lower insurance premiums, for those adopting such measures.[192]

On a different scale, the same potential exists for large infrastructure projects such as hydropower, wastewater treatment, and port facilities. Anticipating severe weather conditions and making appropriate design changes can typically be done for a modest additional cost if implemented at the time of design and construction.[193] A good example of larger-scale infrastructure measures is the management of flooding in the Netherlands, a country with substantial land area reclaimed from the sea. The Dutch government spends over $1 billion annually on water control and much more on barriers; one program alone cost about $13 billion and required more than four decades to complete.[194] After Superstorm Sandy, plans of a similar nature have been proposed to protect Manhattan.[195] In many parts of the world where infrastructure investment is aged or in ill-repair, significant investments will be needed. Incorporating resilience into renewed efforts to close the infrastructure gap can not only make significant strides in reducing climate risks and improving resilience, but can also stimulate the economy and create jobs.

ASS'N, https://www.apawood.org/designerscircle-design-for-wind-resistance (last visited Nov. 6, 2016). Numerous sources provide detailed information on low cost, disaster resistant construction. *See, e.g.*, Joseph Warnes, *Design and Construction of Low-Cost Disaster-Resistant Replacement Houses*, ICF BUILDER MAG. (last visited Nov. 6, 2016), http://www.icfmag.com/articles/features/low_cost_replacement.html; Jenna M. Aker, *The Basics of Passive Fire Protection*, BUILDINGS (Apr. 1, 2008), http://www.buildings.com/article-details/articleid/5851/title/the-basics-of-passive-fire-protection-.aspx. Conversely, those in high-risk areas failing to adopt risk-reducing measures are liable for higher insurance rates—and may have trouble finding coverage. For example, homeowners in areas with increased risk of wildfires due to the drought in California are facing large increases in insurance rates. Samantha Masunaga, *Homeowners in High Fire-Risk Areas are Upset over Soaring Insurance Rates*, L.A. TIMES (Sept. 9, 2015, 4:00 AM), http://www.latimes.com/business/la-fi-fire-insurance-20150909-story.html.

192. *Regulatory Framework for FORTIFIED Insurance Incentives*, INS. INST. FOR BUS. & HOME SAFETY, http://disastersafety.org//wp-content/uploads/FORTIFIED-Incentives1.pdf (last visited Nov. 6, 2016).

193. "Resilience-building adaptations to infrastructure are not expensive if incorporated early in the project lifecycle, with research demonstrating average incremental costs of 1 and 2 percent for infrastructure projects." EMERGING TRENDS IN MAINSTREAMING CLIMATE RESILIENCE IN LARGE SCALE, MULTI-SECTOR INFRASTRUCTURE PPPS, WORLD BANK 1 (2016), https://library.pppknowledgelab.org/attached_files/documents/2874/original/Mainstreaming_Climate_Resilience.pdf?1459201479.

194. Andrew Higgins, *Lessons for U.S. From a Flood-Prone Land*, N.Y. TIMES (Nov. 14, 2012), http://www.nytimes.com/2012/11/15/world/europe/netherlands-sets-model-of-flood-prevention.html. Dutch thinking has reportedly shifted toward more natural, less capital intensive solutions: "The state is investing in a plan . . . to ease flooding by giving waterways space to move and even overflow. Last year, the country spent around $100 million to dump 706 million cubic feet of sand off the coast north of Rotterdam to promote the formation of protective sandbars." *Id.*

195.

> [The proposed gates to protect Manhattan] would go across the narrows, the area below the Verrazano Bridge . . . . The storm comes, warning system warns, and the gates swing closed and Manhattan is protected . . . . We're talking Statue of Liberty [height] . . . . Prices are pretty variant at the moment, but [it's] in the order of $10 billion.

Davies, *supra* note 183 (interview with author McKenzie Funk).

3. Insurance Products and Services

In our current system, a certain level of risk can be underwritten by the private insurance industry, while higher or "uninsurable risks" are absorbed by taxpayers and paid out through disaster relief funding, whether on the state, federal, or international level (via development finance). Traditional insurance measures pay in response to natural disasters; if premiums are properly aligned with risks—which is not necessarily the case—policy costs may bring about changes that can help mitigate damages in the future. A third closely related but distinct category of opportunities involves blending or bundling insurance measures with resilience efforts to stimulate necessary investments. Such programs can be implemented in conjunction with requirements or incentives for changes in behavior or other actions that reduce the impacts of extreme events. For example, insurance for flooding is sometimes linked to raising the level of a structure or moving critical building components (e.g., heating, ventilation, and air conditioning ("HVAC") and backup power generators) to higher levels, and coverage for wildfires can be linked to lower premiums or requirements for the use of fire-retardant materials.[196]

Insurance and reinsurance companies would logically seem to be on the front lines in responding to climate change, which may pose a "double threat" to the insurance industry as a whole. The industry (i) faces increasing costs from claims relating to the physical impacts of climate change and secondary impacts, such as the disruption of global supply chains; and (ii) has an investment portfolio that is exposed to climate risks, particularly if those portfolios are heavily invested in companies that will lose out in the transition to the low-carbon economy.[197] Surveys surprisingly show that the industry has been slow to recognize the risks of climate change and reduce its exposure to fossil fuel investments.[198] Nonetheless, innovative insurance products are showing how climate change risks can be reduced.[199] The introduction and uptake of these products face several challenges, including the very small size of the industry in most developing

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196. *Consumer Advisory: Wildfire Mitigation & Insurance Tips*, COLO. DEP'T OF REG. AGENCIES (Apr. 28, 2016), https://www.colorado.gov/pacific/dora/news/consumer-advisory-wildfire-mitigation-insurance-tips.

197. ASSET OWNERS DISCLOSURE PROJECT, GLOBAL CLIMATE 500 INDEX 2016, at 3 (2016), http://aodproject.net/wp-content/uploads/2016/07/AODP-GCI-2016_INSURANCE-SECTOR-ANALYSIS_FINAL_VIEW.pdf.

198. The NGO Ceres monitors this issue and issues updates periodically. *See* MAX MESSERVY, CERES, INSURER CLIMATE RISK DISCLOSURE SURVEY REPORT & SCORECARD: 2016 FINDINGS AND RECOMMENDATIONS (2016), https://www.ceres.org/resources/reports/2016-insurer-climate-risk-disclosure-survey/view; CYNTHIA MCHALE & ROWAN SPIVEY, CERES, ASSETS OR LIABILITIES? FOSSIL FUEL INVESTMENTS OF LEADING U.S. INSURERS (2016), https://www.ceres.org/resources/reports/assets-or-liabilities-fossil-fuel-investments-of-leading-u.s.-insurers/view. One reason for the slow response of insurers—at least to flooding risks—has arguably been federal policies that subsidize flood protection coverage in flood-prone areas, with the consequence that the system is now heavily in debt. *See* NANCY D. ISRAEL, CERES, INACTION ON CLIMATE CHANGE: THE COST TO TAXPAYERS 12–15 (2013), https://www.ceres.org/resources/reports/inaction-on-climate-change-the-cost-to-taxpayers.

199. Insurance mechanisms are increasingly being seen as a response to climate change because they allow for risk sharing, pooling resources, and rapid response to natural disasters. Three examples:

countries, particularly for property and casualty coverage.[200] Most of the innovation to date has been facilitated and sometimes subsidized by public and private donors. For example, African Risk Capacity ("ARC") was established by the African Union with the specific purpose of reducing the risks of loss and damage caused by extreme weather events on the continent.[201] Funding is provided by country premiums—as well as up-front contributions from donors—and ARC allocates payouts once certain pre-determined triggers are met.[202] In some cases, subsidies may only be necessary to demonstrate commercial viability, while in others, continued public support may be required if commercial returns are marginal but public benefits are large.[203]

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1. Farming is the primary occupation in many developing countries and the most common source of income for an estimated 2.5 billion people worldwide. Dickson Mbando, *How the World's Largest Companies Can Help Africa's Farmers*, WORLD ECON. FORUM (Mar. 29, 2016), https://www.weforum.org/agenda/2016/03/how-the-worlds-largest-companies-can-help-africas-farmers. Weather-index insurance pays benefits on the basis of pre-determined metrics for rainfall, temperature, and other indicators, and payments can be made quickly to mitigate the harmful effect of crop losses. WORLD FOOD PROGRAMME & INT'L FUND FOR AGRIC. DEV., WEATHER INDEX-BASED INSURANCE IN AGRICULTURAL DEVELOPMENT 18 (2011), https://www.ifad.org/documents/10180/2a2cf0b9-3ff9-4875-90ab-3f37c2218a90.
2. Disaster relief programs are traditionally a government responsibility, with donor help often provided to poor countries after extreme weather events. An insurance mechanism, African Risk Capacity, operates a risk pool that provides participating African governments payments for pre-approved disaster relief programs tied to agreed weather events (to date limited to droughts). *See How ARC Works*, AFRICAN RISK CAPACITY (Oct. 29, 2016), http://www.africanriskcapacity.org/2016/10/29/how-arc-works/. For recent challenges in the administration of ARC funds, see *ARC's Covenant: A Worthy Insurance Scheme Goes Awry*, THE ECONOMIST (Aug. 27, 2016), http://www.economist.com/news/finance-and-economics/21705856-worthy-insurance-scheme-goes-awry-arcs-covenant.
3. Many developing countries generate a substantial amount of their power through hydroelectric plants. In lower water years, they either have power shortages with costly reductions in economic activity, or they generate power using costly oil imports. A weather-risk insurance policy in Uruguay facilitated by the World Bank and administered by Swiss Re insures against the frequent lack of rain. Press Release, World Bank, World Bank Partners with Uruguay to Execute Largest Public Weather and Oil Price Insurance Transaction (Dec. 19, 2013), http://www.worldbank.org/en/news/press-release/2013/12/19/world-bank-uruguay-public-weather-oil-price-insurance-transaction. Similar instruments are now being developed for wind farms to protect against reductions in output and revenue during unusually low wind years. *Id.*

200. Alan Miller & Stacy Swann, *EMCompass Note 9: Innovative Insurance to Manage Climate Risks*, INT'L FIN. CORP. (Sept. 2016), https://www.ifc.org/wps/wcm/connect/d6407581-5ad1-4144-abe2-df06e5f3168c/Note-9-EMCompass-Innovative-Insurance-to-Manage-Climate-Risks.pdf?MOD=AJPERES; Alan Miller & Stacy Swann, *EMCompass Note 13: Insurance Options for Addressing Climate Change*, INT'L FIN. CORP. (Sept. 2016), http://www.ifc.org/wps/wcm/connect/739a5af0-d26c-4ce5-a9ff-d6f49f801bf9/Note-13-EMCompass-Insurance-Options-for-Addressing-Climate-Change.pdf?MOD=AJPERES.

201. *See* AFRICAN RISK CAPACITY, *supra* note 199.

202. *See id.* By merging the traditional approaches of disaster relief with the concepts of risk pooling and risk transfer, ARC capitalizes on the natural diversification of weather risk across Africa, allowing countries to manage their risk as a group in a financially efficient manner in order to respond to probable but uncertain risks. *Id.*

203. Index insurance for small farmers in developing countries has also been shown to be a good economic

4. New Markets Created by a Warming Planet

A fourth category consists of business opportunities made possible only because of some of the significant environmental changes expected due to global warming, such as glacial melting. A prime example is the potential for shipping through the Russian Arctic or Northwest Passage above Canada with the melting of sea ice. China recently announced plans to help ships under its flag navigate the Arctic via a route that is thirty percent shorter than the ocean passages traditionally used to connect the northern Atlantic and Pacific Oceans through the Panama Canal.[204] In agriculture, some areas with historically limited growing seasons due to cold temperatures may also offer promising opportunities for greater production, assuming appropriate soil conditions, the availability of water, and the necessary infrastructure.[205] Many foods—such as coffee, chocolate, and wine—are tied to very specific locations and climes, and thus face an uncertain future.[206]

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investment, but in many cases farmers are unwilling or unable to pay for it. The initial costs and risks associated with offering insurance products for low-income farmers is a major disincentive for commercial insurance companies. Gloria M. Grandolini, *Can Index Insurance Protect Poor Farmers Against Climate Risks?*, WORLD BANK (Sept. 14, 2015), http://blogs.worldbank.org/psd/can-index-insurance-protect-poor-farmers-against-climate-change-risks. For a good review of experience and lessons learned in the design and implementation of index insurance programs for small farmers, including efforts to scale up participation, see HELEN GREATREX ET AL., CGIAR RES. PROGRAM ON CLIMATE CHANGE, AGRIC. & FOOD SEC., REPORT NO. 14, SCALING UP INDEX INSURANCE FOR SMALL FARMERS: RECENT EVIDENCE AND INSIGHTS (2015), https://cgspace.cgiar.org/bitstream/handle/10568/53101/CCAFS_Report14.pdf?sequence=1.

204. Peng Yining, *China Charting a New Course*, CHINA DAILY (Apr. 20, 2016, 2:50 AM), http://www.chinadaily.com.cn/china/2016-04/20/content_24679000.htm. To encourage shippers to consider the shorter but still dangerous route, China published a 356-page guide to navigating the Passage, including nautical charts and advice on how to handle sea ice. *Id.*

205. Agriculture modeling to test the impact of warmer temperatures shows a global decline in productivity, but some localized benefit in colder countries like Russian and Canada. This is a troubling result insofar as poor countries are expected to suffer the most as temperatures rise. According to one detailed analysis, average income in the poorest forty percent of countries declines seventy-five percent relative to a world without climate change, while the richest twenty percent experience small gains. Burke et al., *supra* note 99, at 238; *see also* Senthold Asseng et al., *Rising Temperatures Reduce Global Wheat Production*, 5 NATURE CLIMATE CHANGE 143 (2015), www.nature.com/nclimate/journal/v5/n2/abs/nclimate2470.html; Senthold Asseng et al., *Has Climate Change Opened New Opportunities for Wheat Cropping in Argentina?*, 117 CLIMATIC CHANGE 181 (2013), http://link.springer.com/article/10.1007/s10584-012-0553-y.

206. Alan Miller, *Save the Chocolate and the Planet*, WORLD BANK (Nov. 17, 2011), http://blogs.worldbank.org/climatechange/save-chocolate-and-planet. Starbucks has warned that climate change is a threat to the production and quality of the coffee supply. Nanette Byrnes, *Starbucks Responds to Climate Change, with Mixed Results*, MIT TECH. REV. (May 9, 2016), https://www.technologyreview.com/s/601404/starbucks-responds-to-climate-change-with-mixed-results/. Bananas are another crop that is subject to changes in yields and diseases due to climate change. *Banana Boom and Bust as Climate Changes*, CGIAR RES. PROGRAM ON CLIMATE CHANGE, AGRIC. & FOOD SEC. (Oct. 4, 2011), https://ccafs.cgiar.org/blog/bananas-will-face-climate-stress#.V6X5CrgrKUk. Yet another crop threatened by climate change is hops, an essential ingredient for making beer. Eilis O'Neill, *The Climate for Making Beer is Changing, So Brewers and Hops Growers Are Too*, PUB. RADIO INT'L (Oct. 26, 2016, 1:30 PM), http://www.pri.org/stories/2016-10-26/climate-making-beer-changing-so-brewers-and-hops-growers-are-too.

Some of the more exciting developments are those that involve the creation of new business models. For example, by integrating concepts from Tesla and Solar City, Elon Musk is betting that there will have to be a new paradigm for consumer power consumption and transportation—namely, solar generation, battery storage, and electric cars—and that these can be offered as one complete package.[207] This vision is achievable only by creating an entirely new market of consumer demand for these bundled services, but it is fundamentally based on his knowledge that approaches to both energy generation and transportation necessarily need to change if we are to meet the ambition to stay within a two-degree Celsius world.[208]

IV. SUPPORTIVE GOVERNMENT POLICIES

Addressing climate risks, and capturing the opportunities to become more resilient, can be accelerated by supportive government policies. In many places, governments are already implementing policies to encourage the transition to a low-carbon economy, including better energy regulations or fuel-efficiency standards, as well as improvements in building codes, more accurate flood zone mapping, or policies that address water challenges.[209]

However, integrating climate considerations into financial policies—both those that affect the financial systems and how insurance, banking, and investment are regulated, and those that create incentives for better investments—will be one of the more critical areas of government policymaking. These considerations can help focus much of financing on the efforts to manage climate risks and "build in" resilience across the economy. Furthermore, supportive and complementary government policies can help demonstrate that actions to address climate change can be attractive opportunities for private investment, which will (ideally) contribute to a virtuous cycle where investments support climate policies and vice versa.

The good news is that, in many parts of the world, policymakers have been making strides to incentivize investments which support a two-degree world, and more recently have begun to look at ways to foster greater regulation of disclosure and transparency of climate risks, and in some cases address pricing distortions through carbon prices. New instruments, incentives, and institutions

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207. Cassandra Sweet, *Elon Musk Has Big Hopes for Storage Batteries, but the Market is Small*, WALL ST. J. (Aug. 8, 2016, 1:23 PM), http://www.wsj.com/articles/elon-musk-has-big-hopes-for-storage-batteries-but-the-market-is-small-1470676986?mod=mktw.

208. *Id.*

209. For example, the E.U. has a comprehensive regional emission reduction target and trading system. *See European Climate Change Programme*, EUR. COMM'N, http://ec.europa.eu/clima/policies/eccp/index_en.htm (last updated Nov. 25, 2016). And Bangladesh has invested in flood management and emergency shelters in response to increased storm intensity and sea-level rise. *See* MINISTRY OF ENV'T & FORESTS, GOV'T OF THE PEOPLE'S REPUBLIC OF BANGL., BANGLADESH CLIMATE CHANGE STRATEGY AND ACTION PLAN 2009 (2009), http://cmsdata.iucn.org/downloads/bangladesh_climate_change_strategy_and_action_plan_2009.pdf.

are growing: green bonds, green banks, and tax policies to scale up clean energy have all contributed to greater engagement by the private sector and finance.[210] This is positive news for our overall efforts to keep emissions in check and limit warming to two degrees Celsius.

However, we are already "locked in" to the need to adapt to a changing climate, and our emissions to date mean that we will need to "build in" resilience for that future. Greater data, analytics, and tools will enable governments, the private sector, finance, and communities to better understand those risks unique to each context and circumstance. Having good climate data and analytics is a necessary condition and the foundation of any risk mitigation strategy, whether it involves "building-in" resilience measures to physical assets, or understanding weaknesses in supply chains and planning for redundancies.

Though the Paris Agreement was historic, the real work is still to come. The momentum gathered to bring the business and finance community needs to remain high, given the magnitude of the transformation required to achieve the Paris goals. Now, more than ever, there needs to be greater involvement of businesses and finance in the development of climate policies, approaches, and programs to ensure that we reduce our emissions and "build in" resilience for the future. This includes those entities focused on helping us identify, assess, and manage climate risks of all types. Cross-sector engagement should continue to happen internationally through forums like the G20, the FSB, and others. This engagement also needs to continue at the national level in the development of climate and infrastructure plans, and at the sub-national level where states and cities are often on the front lines in dealing with issues central to mitigation and adaptation, including land use and transportation planning, building regulation, and disaster-response planning. Governments, businesses, investors, and financial institutions across the entire financial-services sector will need to collaborate to align the public interest in addressing climate change much more closely with financial incentives, risk-return criteria, and ultimately the opportunities to address climate risks and invest in resilience.

It is clear that there is a symbiotic relationship between the correct supportive policies, climate-risk management, the transition to a low-carbon economy, and "building in" resilience to a warming planet. Economic impacts of climate change are a compelling reason for policymakers to promote supportive financial policies that can help accelerate the transition to a low-carbon economy. For the

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210. An ongoing project of the U.N. Environment Programme, the UNEP Inquiry into the Design of a Sustainable Financial System, has produced a series of reports that underscore the policy and instruments required to transition to a sustainable, low-carbon economy. Their research recommends scaling up financial-market policy and regulatory innovations that would support the development of a green financial system, including scaling up green bonds, establishing national-level green-investment banks, support for carbon pricing, and other policy incentives. *See UNEP Inquiry*, U.N. ENV'T PROGRAMME, http://web.unep.org/inquiry (last visited Nov. 27, 2016).

private sector, the risks to financial returns are also a compelling reason to encourage good financial policymaking that allows for transparent information flows about climate risks, and reduces subsidies to activities that are counter to a low-carbon transition or might "lock in" investment in infrastructure that is not compatible with a two-degree world. These changes also bring significant opportunity, if acted on quickly enough. Addressing climate change brings the possibility of integrating resilience into infrastructure; developing new tools and analytics to help decisionmakers across industry and finance better assess, plan, and mitigate against climate risks; and can, in some cases, present opportunities for new markets and services.