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Climate Services: The Business of Physical Risk

Madison Condon

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A growing number of investors, insurers, financial services providers, and nonprofits rely on information about localized physical climate risks, like floods, hurricanes, and wildfires. The outcomes of these risk projections have significant consequences in the economy, including allocating investment capital, impacting housing prices and demographic shifts, and prioritizing adaptation infrastructure projects. The climate risk information available to individual citizens and municipalities, however, is limited and expensive to access. Further, many providers of climate services use black box models that make overseeing the scientific rigor of their methodologies impossible—a concern given scientific critiques that many may be obfuscating the uncertainty in their projections. Municipalities that want to challenge insurance and bond rating determinations must rally significant resources for modeling and data, a scattershot policing method at best. And when companies have access to sophisticated modeling about future impacts—some of them potentially devastating for entire communities—the decision to share that information has been largely left up to the corporation.

This Article argues that actionable and transparent information about our climate-changed future is a public good that the private sector cannot be depended upon to provide equitably or reliably. Further, all private climate services rely on upstream climate data and models that were collected and produced by an enormous network of public institutions. There are important

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lessons to be learned from the recent success of special interests in pressing for the privatization of weather data and services—a trend that has knock-on effects for weather forecasts globally. This Article urges state and federal governments to invest in their own climate services capacity at a scale not currently contemplated. Risk assessments lacking a scientific basis can lead to maladaptation across the economy. While it is a potentially limited matter of consumer protection or tort liability when a consultancy over-promises its analytical capabilities, it is a much larger problem if regulators themselves misunderstand the limits of uncertainty when designing risk oversight.

TABLE OF CONTENTS

INTRODUCTION

After tremendous wildfires in Oregon destroyed 4,000 homes in the summer of 2021, the state legislature passed a sweeping law meant to reduce future wildfire loss.[1] Because the law targets regulations and funding to the riskiest areas, it directed the Department of Forestry to work with Oregon State University to produce a map of wildfire risk covering each tax lot in the state—drawing together datasets on weather, climate, topography, and vegetation.[2] Officials were unprepared for the level of public outrage that met the map's online unveiling in June 2022.[3] Homeowners received letters in the mail if they lived in a lot classed as either "high" or "extreme" wildfire risk, giving many an unwanted surprise.[4] Thousands of people attempted to contact forestry officials, and hundreds of risk classification appeals were submitted before the state shut down the process five weeks later, withdrawing the map entirely.[5] Questions were raised over the map's accuracy, with confusion as to why neighboring houses fell into different risk classes, or why a house was labeled risky despite work adopting fire-protection measures.[6] Regulators admitted that in the rush to meet the law's deadline, "there wasn't enough time to allow for the type of local outreach and engagement that people wanted, needed and deserved."[7]

A main concern focused on the map's effect on insurance premiums and property values—some homeowners assumed that the map was tied to their own insurer's recent decision not to renew a longstanding policy.[8] This fear

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1. Erika Bolstad, *Wildfire Maps Underscore Risks—and Costs—of Climate Change*, STATELINE, AN INITIATIVE OF THE PEW CHARITABLE TRS. (Aug. 29, 2022), https://pew.org/3AtSQeC [https://perma.cc/QG7S-N3JP].

2. *Wildfire Risk*, OR. DEP'T OF FORESTRY, https://www.oregon.gov/odf/fire/pages/wildfire-risk.aspx [https://perma.cc/N3U2-JRS9].

3. Jake Bittle, *Oregon Tried to Inform Residents About Wildfire Risk. The Backlash Was Explosive.*, GRIST (Nov. 2, 2022), https://grist.org/housing/oregon-wildfire-risk-map-home-values/ [https://perma.cc/J55N-TAGM].

4. Christina Giardinelli, *Oregon Lawmakers, Insurance Commissioner Respond to Wildfire Map Concerns*, KATU (Aug. 8, 2022), https://katu.com/news/local/oregon-lawmakers-insurance-commissioner-respond-to-wildfire-map-concerns [https://perma.cc/2JEH-VSQV].

5. Cassandra Profita, *Swamped by Public Outcry, Oregon Withdraws Controversial Wildfire Risk Map*, OR. PUB. BROAD. (Aug. 5, 2022, 3:54 PM), https://www.opb.org/article/2022/08/05/oregon-wildfire-prevention-map-risk-forest-fire-insurance/ [https://perma.cc/TM4S-8TPH].

6. *Id.*

7. Gillian Flaccus, *Oregon's Wildfire Risk Map Emerges as New Climate Flashpoint*, ASSOCIATED PRESS (Aug. 5, 2022), https://apnews.com/article/wildfires-science-fires-oregon-evangelism-8342f786db7850a2aca3163acb6d5574 [https://perma.cc/BD7V-4Y7R].

8. Cassandra Profita, *What Is Your Home's Risk of Wildfire? New Statewide Map Can Tell You*, OR. PUB. BROAD. (June 30, 2022, 6:19 PM), https://www.opb.org/article/2022/06/30/oregon-

was so pervasive that the Oregon Department of Financial Regulation issued a formal "data call" to all insurers, requiring them to answer whether they had used, or planned to use, the map—sending a press release when each company had answered no.[9] When constituents asked a House Representative supporting the wildfire measures why she thought insurance companies would not take advantage of the risk map that the state had spent $2 million dollars to build, she responded that insurers already had their own proprietary data, and that the purpose of the map was to "tell ratepayers what insurance companies already know."[10] Wildfire policy expert Michael Wara agreed in an interview that insurers "have way better maps."[11]

This Article is about these maps, and the industry of "climate services" that works to produce the data, methods, and models that go into building them.[12] Do insurers have better maps? How would we know? What about ratings agencies—what maps are they using to analyze Miami's various municipal bonds? The uproar from homeowners in Oregon may be understandable, but it is also ironic in at least two ways. First, the law's aim to promote transparent information about risk was partially motivated by homeowner worries about "secret formulas" used by insurers; regulators in California recently responded to "wildfire risk scores that many did not know existed and had no right to appeal if inaccurate."[13] The second irony is that one month before the state's rollout of the public map, new nationwide "Fire Factor" scores had been unveiled by climate analytics group First Street Foundation. These and similar scores were now embedded in websites like

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wildfire-prevention-map-risk-forest-fire-home/ [https://perma.cc/C4WJ-LZXL]; Alex Baumhardt et al., *Insurance Rates Will Not Rise Due to New Oregon Wildfire Risk Map, State Regulators Say*, OR. CAPITAL CHRONICLE (Aug. 15, 2022), https://oregoncapitalchronicle.com/2022/08/15/insurance-rates-will-not-rise-due-to-new-oregon-wildfire-risk-map-state-regulators-say/ [https://perma.cc/E6NB-24SM].

9. Bolstad, *supra* note 1; *Division of Financial Regulation: Oregon Division of Financial Regulation: Insurance Companies Not Using State Wildfire Risk Map*, OR. DIV. OF FIN. REGUL. (Aug. 12, 2022), https://dfr.oregon.gov/news/news2022/Pages/20220812-wildfire-risk-map.aspx [https://perma.cc/T8ZR-F8HC].

10. Giardinelli, *supra* note 4.

11. Flaccus, *supra* note 7.

12. The growing world of "climate services" has received little attention in the legal literature, despite the fact that an entire CLIMATE SERVICES journal exists, mostly covering Europe and the Global South. *See, e.g.*, Jörg Cortekar et al., *Systematic Analysis of EU-Based Climate Service Providers*, 17 CLIMATE SERVS. 100125, 125 (2020).

13. Press Release, Ricardo Lara, Ins. Comm'r, California Dep't of Ins., Commissioner Lara Enforces Nation's First Wildfire Safety Regulation to Help Drive Down Cost of Insurance (Oct. 17, 2022), https://www.insurance.ca.gov/0400-news/0100-press-releases/2022/release076-2022.cfm [https://perma.cc/24PN-6KNY].

Realtor.com and Redfin.com—homeowners could search their addresses to see whether prospective buyers were told their house had extreme fire risk.[14]

An increasing number of consultancies, financial technology firms, data providers, and investment advisory groups offer information about localized physical climate risks, like floods, hurricanes, and wildfires.[15] The past few years have seen rapid consolidation of companies that offer "environmental, social, and governance" ("ESG") related financial analysis, with more than fifty providers merged into a handful of financial services firms, like ratings agencies and index providers.[16] Included in this consolidation were many of the early players in physical risk "climate analytics," like Moody's 2019 purchase of industry leader Four Twenty Seven.[17] In the accelerating "climate intelligence arms race," companies increasingly claim to use better science, better methods and models, and more comprehensive data than their competitors.[18]

But the "black box" proprietary nature of methods and metrics make them hard to compare, let alone oversee.[19] And the value chain of climate services extends from upstream government institutions collecting weather data and running models on supercomputers, to downstream consultancies that assess and communicate localized risk.[20] So it can be difficult for an end-user to determine where data was sourced and what value was added by a given provider. The physical risk scores produced by leading ESG firms have been

14. Steve Goode, *Realtor.Com Offers Wildfire Risk Data*, NAT'L MORTG. PRO. (May 16, 2022), https://nationalmortgageprofessional.com/news/realtorcom-offers-wildfire-risk-data [https://perma.cc/34PN-KXQK].

15. *See infra* Section I.B.

16. *See* Andreas Dimmelmeier, Mergers and Acquisitions of ESG Firms: Towards a New Financial Infrastructure? (Oct. 13, 2020) (unpublished manuscript) (available at http://dx.doi.org/10.31235/osf.io/jt2uk [https://perma.cc/T7SX-YZBC]); *see also* Leslie P. Norton, *Moody's CEO Sees 'Need to Better Understand the Financial Impacts of Climate Change*', BARRON'S (Aug. 9, 2021, 5:30 AM), https://www.barrons.com/articles/moodys-ceo-sees-need-to-better-understand-the-financial-impacts-of-climate-change-51628374322 [https://perma.cc/Y3P2-VQ7Z].

17. Norton, *supra* note 16; *see also Moody's Acquires Majority Stake in Four Twenty Seven, Inc., a Leader in Climate Data and Risk Analysis*, BUS. WIRE (July 24, 2019, 7:00 AM), https://www.businesswire.com/news/home/20190724005169/en/Moody%E2%80%99s-Acquires-Majority-Stake-in-Four-Twenty-Seven-Inc.-a-Leader-in-Climate-Data-and-Risk-Analysis [https://perma.cc/F45U-T8Q3].

18. *See* Jesse M. Keenan, *A Climate Intelligence Arms Race in Financial Markets*, 365 SCIENCE 1240, 1240 (2019); *see also, e.g.*, Tom Mortlock, *The Value of CAT Models for Measuring Climate Risk*, AON INSIGHTS (Jul. 12, 2022), https://aoninsights.com.au/the-value-of-cat-models-for-measuring-climate-risk/ [ ] (noting the "strong dose of marketing" in the "debate simmering at the moment as to whether catastrophe loss (CAT) models or climate risk models are best for modelling the financial impacts of physical climate risk").

19. *See infra* Section II.A.

20. *See infra* Section I.

found to have little correlation with one another.[21] While there is enormous demand from the private sector for useful risk assessment, there is little in-house capacity to evaluate products.[22] There is growing recognition by the scientific community that global climate models are being applied to problems they were not designed to analyze.[23] Academics have similarly flagged that private providers can over-claim what science is able to predict at small geographic scales, or particular time-scales.[24]

The outcomes of these risk assessments have significant consequences in the economy. They are used to allocate equity capital through active and passive investment strategies.[25] They influence insurance premiums, impacting housing prices and causing demographic shifts.[26] They are considered in municipal bond ratings, thereby serving as a mechanism of prioritizing city- and county-level adaptation infrastructure projects.[27] The cost of physical risk datasets and climate risk consulting services can reach into the millions.[28] Municipalities that want to challenge insurance and bond rating determinations must rally significant resources for modeling and data,

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21. Linda I. Hain et al., *Let's Get Physical: Comparing Metrics of Physical Climate Risk*, 46 FIN. RSCH. LETTERS 1, 3 (2022).

22. Alicia Karspeck, *Adding Climate Risk in Investment Assessments Is No Passing Trend*, BLOOMBERG L. (July 14, 2021, 1:00 AM), https://news.bloomberglaw.com/environment-and-energy/adding-climate-risk-in-investment-assessments-is-no-passing-trend [https://perma.cc/W95V-5B85].

23. *See, e.g.*, NICOLA A. RANGER ET AL., ASSESSING FINANCIAL RISKS FROM PHYSICAL CLIMATE SHOCKS: A FRAMEWORK FOR SCENARIO GENERATION 12 (2022); A.J. Pitman et al., *Acute Climate Risks in the Financial System: Examining the Utility of Climate Model Projections*, 1 ENV'T RSCH.: CLIMATE 1, 4 (2022).

24. Tanya Fiedler et al., *Business Risk and the Emergence of Climate Analytics*, 11 NATURE CLIMATE CHANGE 87, 91 (2021).

25. *See, e.g.*, Tim Antonelli, *Mapping the Impact of Climate Change*, WELLINGTON MGMT. (Jan. 2021), https://www.wellington.com/en-latam/intermediary/insights/climate-exposure-risk-analysis [https://perma.cc/Y6J5-GHYB]; JASPREET DUHRA & MUHAMMAD MASOOD, *Do Physical and Transition Climate Risks Translate Into Investment Risks?*, S&P DOW JONES INDICES 1, 6 (2021), https://www.spglobal.com/spdji/en/documents/education/education-do-physical-and-transition-climate-risks-translate-into-investment-risks.pdf [https://perma.cc/M3B9-SMLN]; *S&P Paris-Aligned & Climate Transition (PACT) Indices Methodology*, S&P DOW JONES INDICES 1, 45 (2023), https://www.spglobal.com/spdji/en/documents/methodologies/methodology-sp-paris-aligned-climate-transition-pact-indices.pdf [https://perma.cc/SLJ4-SALL].

26. REBECCA ELLIOTT, UNDERWATER: LOSS, FLOOD INSURANCE, AND THE MORAL ECONOMY OF CLIMATE CHANGE IN THE UNITED STATES 1–11 (Columbia Univ. Press 2021); Zac J. Taylor & Manuel B. Aalbers, *Climate Gentrification: Risk, Rent, and Restructuring in Greater Miami*, 112 ANNALS AM. ASS'N GEOGRAPHERS 1685, 1685 (2022).

27. Savannah Cox, *Inscriptions of Resilience: Bond Ratings and the Government of Climate Risk in Greater Miami, Florida*, 54 ENV'T & PLAN. A: ECON. & SPACE 295, 295 (2021).

28. Alice C. Hill, *COVID's Lesson for Climate Research: Go Local*, 595 NATURE 9, 9 (2021).

a scattershot policing method at best. When companies have access to sophisticated modeling about future impacts—some of them potentially devastating for entire communities—the decision to share that information has been largely left up to the corporation.[29] This Article's anecdotal documentation of the private sector's use of this information is partially motivated by the question: Is this "cutting edge" data being used in the best way—could it be used to mitigate risk, for more people, rather than hedge it for some?[30]

Despite the federal government's linchpin role of developing resource-intensive global climate models, it has arguably lagged the private sector in the production and broad dissemination of "usable" climate science—that is, science aimed at the scale of adaptation decisions.[31] The Biden administration's "whole-of-government" approach to climate change has given many agencies a climate risk mandate, with little existing staff capacity or expertise.[32] The Office of the Comptroller of the Currency ("OCC"), the Federal Insurance Office ("FIO"), the Federal Deposit Insurance Corporation ("FDIC"), and the Federal Housing Finance Administration ("FHFA"), are just a few of the many regulatory agencies scrambling to get up to speed on how to integrate climate science into financial risk assessments.[33] As the

29. *See, e.g.*, Christopher Flavelle & Jeremy C. F. Lin, *Rising Waters Are Drowning Amtrak's Northeast Corridor*, BLOOMBERG (Dec. 20, 2018), https://www.bloomberg.com/graphics/2018-amtrak-sea-level/ [https://perma.cc/F8DP-JWTZ].

30. *Cf.* Zac J. Taylor, *The Real Estate Risk Fix: Residential Insurance-Linked Securitization in the Florida Metropolis*, 52 ENV'T & PLAN. A: ECON. & SPACE 1131 (2020) (discussing the role of climate risk assessment in insurance-linked securitization).

31. Adam H. Sobel, *Usable Climate Science Is Adaptation Science*, 166 CLIMATIC CHANGE 1 (2021).

32. *See* Exec. Order No. 14,030, 86 Fed. Reg. 27967 (May 25, 2021); *FACT SHEET: Biden Administration Roadmap To Build an Economy Resilient to Climate Change Impacts*, WHITE HOUSE (Oct. 15, 2021), https://www.whitehouse.gov/briefing-room/statements-releases/2021/10/15/fact-sheet-biden-administration-roadmap-to-build-an-economy-resilient-to-climate-change-impacts/ [https://perma.cc/2N7V-G68S] (announcing "[t]he Administration's whole-of-government strategy . . . to achieve the goals of the President's May 2021 Executive Order on Climate-Related Financial Risks"). One recent exception to the lack of scientific staffing is the hiring of Dr. Nina Chen to serve as Chief Climate Risk Officer in charge of the OCC's new Office of Climate Risk. *See* Richard Vanderford, *U.S. Banking Regulator Appoints New Climate Risk Chief*, WALL ST. J. (Sept. 12, 2022, 4:01 PM), https://www.wsj.com/articles/u-s-banking-regulator-appoints-new-climate-risk-chief-11663012908 [https://perma.cc/SZU6-9NVT].

33. *See, e.g.*, *Risk Management: Principles for Climate-Related Financial Risk Management for Large Banks; Request for Feedback*, OFF. OF THE COMPTROLLER OF THE CURRENCY (Dec. 16, 2021), https://www.occ.treas.gov/news-issuances/bulletins/2021/bulletin-2021-62.html [https://perma.cc/7QYB-NS35]; OFF. OF THE DIR., FED. HOUS. FIN. AGENCY, CLIMATE AND NATURAL DISASTER RISK MANAGEMENT AT THE REGULATED ENTITIES 3 (2021); Evan Weinberger, *Fair Lending, Climate Risk Top FDIC Agenda Now Set by Democrats*,

Securities and Exchange Commission ("SEC") begins to demand expanded climate risk disclosures from public companies, how will the regulator assess and enforce claims about future physical risk?[34] How will the SEC oversee the climate risk analysis methodologies of pseudo-regulatory third parties, like ratings agencies?[35]

Part of the Biden administration's answer to these questions may lie in the U.S. Department of the Treasury's July 2022 announcement of a planned "Climate Data and Analytics Hub."[36] The Hub will serve as a convening resource between the Federal Reserve ("Fed") and Treasury, with plans to expand access to the other federal financial regulatory agencies.[37] Gaps in data are frequently cited as a major impediment to financial oversight of climate risks, and the Hub is part of a global trend to build "data lakes" that organize many different types of climate data in one location for multiple users to access.[38] While the Hub includes datasets from federal science agencies, like the National Oceanographic and Atmospheric Administration ("NOAA") and NASA (along with other data from other public and private providers), it appears that the Treasury's Office of Financial Research ("OFR") has not hired scientists to assist in data analysis, and there are no signs of direct collaboration between financial and scientific agencies.[39] Outside of the United States, scientists with expertise in climate extremes warn that financial regulators are making some of the same mistakes as private climate services providers, including designing risk disclosure

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BLOOMBERG L. (Feb. 7, 2022, 9:30 AM), https://www.bloomberglaw.com/bloomberglawnews/banking-law/X6DOT13C000000?bna_news_filter=banking-law#jcite [https://perma.cc/8SSU-D5VM]; *Treasury's Federal Insurance Office Continues Efforts on Climate-Related Financial Risks in the Insurance Sector, Joins the NGFS*, U.S. DEP'T OF THE TREASURY (Feb. 17, 2022), https://home.treasury.gov/news/press-releases/jy0598 [https://perma.cc/3N7P-M98G].

34. *See* The Enhancement and Standardization of Climate-Related Disclosures for Investors, 87 Fed. Reg. 21334, 21351–52 (Apr. 11, 2022) (to be codified at 17 C.F.R. pts. 210, 229, 232, 239, 249) (proposing that issuers disclose material physical risks at zip-code level and report on percentage of physical assets exposed to water stress and/or located in flood plain).

35. *See generally* Frank Partnoy, *What's (Still) Wrong with Credit Ratings?*, 92 WASH. L. REV. 1407 (2017) (discussing the shortcomings and lack of true informational value of credit ratings).

36. Press Release, U.S. Dep't of the Treasury, Office of Financial Research Pilots Cutting-Edge Data Hub to Assist with Climate-Risk Assessments (July 28, 2022), https://home.treasury.gov/news/press-releases/jy0895 [https://perma.cc/LTQ9-KXXY].

37. *Id.*

38. *Destination Earth | Shaping Europe's Digital Future*, EUR. COMM'N, https://digital-strategy.ec.europa.eu/en/policies/destination-earth [https://perma.cc/22NL-9FU2].

39. U.S. Dep't of the Treasury, *supra* note 36.

requirements that misunderstand what global climate models are able to tell us.[40]

As financial regulators build out their ability to monitor climate risks, another group within the Biden administration is working to provide better public-facing information on climate risks.[41] The U.S. Climate Resilience Toolkit is a website with an increasing number of resources, including how municipalities can access federal grant funding for climate adaptation.[42] This Article argues that these two workstreams, one internally facing and focused on financial risk, and another externally focused on resilience and adaption in the "real" U.S. economy, must be better integrated at both the policy and technical level. Whether a factory or a luxury condo is resilient to hurricane risk depends, in part, on its location and projected climate conditions, but it also depends on the resilience of the surrounding municipality. A building that has zero flood risk is not very useful if all the roads leading to the building are washed out. This systemic aspect of climate change related risks requires proactively considering where we think capital should go, not only where we think it will go.

Calls for a National Climate Service ("NCS")—a federal entity that would provide location-specific climate and adaptation information for free—have been around since the 1970s and continue to this day.[43] In 2021, the idea was championed by several members of the House of Representatives.[44] Advocates for an NCS argue that climate change adaptation information is a public good, akin to the National Weather Service's free forecasting and provision of data.[45] This Article embraces the public good framework and argues that the private sector cannot be relied upon to provide climate services equitably or reliably. Further, all private

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40. Fiedler et al., *supra* note 24; Pitman et al., *supra* note 23.

41. *FACT SHEET: Biden Administration Makes Climate Information and Decision Tools More Accessible*, WHITE HOUSE (Oct. 12, 2021) https://www.whitehouse.gov/briefing-room/statements-releases/2021/10/12/fact-sheet-biden-administration-makes-climate-information-and-decision-tools-more-accessible/ [https://perma.cc/CJR3-6MV4]; OFF. OF SCI. & TECH. POL'Y ET AL., OPPORTUNITIES FOR EXPANDING AND IMPROVING CLIMATE INFORMATION AND SERVICES FOR THE PUBLIC: A REPORT TO THE NATIONAL CLIMATE TASK FORCE 26 (2021), https://downloads.globalchange.gov/reports/eo-14008-211-d-report.pdf [https://perma.cc/DP5R-XGF9].

42. *U.S. Climate Resilience Toolkit*, NAT'L OCEANIC & ATMOSPHERIC ADMIN., https://toolkit.climate.gov/ [https://perma.cc/5JFN-JLN7].

43. Roberta Kwok, *US Considers a National Climate Service*, NATURE (Feb. 19, 2009), https://www.nature.com/articles/news.2009.108 [https://perma.cc/NXU8-TLS4].

44. *See Working Towards Climate Equity: The Case for a Federal Climate Service: Hearing Before the H. Subcomm. on Env't*, 117th Cong. (2021).

45. *See, e.g.*, NAT'L OCEANIC & ATMOSPHERIC ADMIN. SCI. ADVISORY BD., OPTIONS FOR DEVELOPING A NATIONAL CLIMATE SERVICE 35 (2009).

climate services rely on upstream climate data and models that were collected and produced by an enormous network of public institutions.[46]

Not only do financial regulators need support for understanding the science behind these claims, but as all agencies begin to take climate change seriously, their own response must be informed by a broader number of climate experts beyond economists. There is a growing understanding that certain "top-down" economic models simplify the complexities of climate science to the point where the models are not only wrong, they are not useful.[47] This is not to say that all physical risk assessments are misleading—indeed it is urgent that we better understand what is ahead so that we can prepare. This Article attempts to provide a science-heavy crash course into what climate models can and cannot tell us about near-term risk, for the purposes of more broadly informing the law, policy, and finance communities.

The Article proceeds as follows. Part I describes where climate risk information comes from, laying out the "value chain" and overview of market players. Part II critiques the current state of climate services for its lack of quality-control and transparency. The current privatization of climate risk information mirrors the trend in the weather data and services industry, and this Part borrows critiques from scholars who have argued against the marketization of weather data. Part III argues that a National Climate Service is needed, both to provide climate risk information tools for the public and to guide regulatory decision-making.

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46. *Cf.* MARIANA MAZZUCATO, THE ENTREPRENEURIAL STATE: DEBUNKING PUBLIC VS. PRIVATE SECTOR MYTHS (2013) (calling out the myth that the public sector plays a small role in innovation and growth and highlighting, for example, that the iPhone's success depends upon key technologies initially invented by public institutions); *id.* at 179-194 (arguing that the public should question whether we get enough in return when we allow the private sector to capitalize on and corner research undertaken by public institutions).

47. *Cf.* George E. P. Box, *Science and Statistics*, 71 J. AM. STAT. ASS'N 791 (1976); Kate Mackenzie, *What Smart People Get Wrong About Climate Change Extremes*, BLOOMBERG (Sept. 20, 2021, 3:00 AM), https://www.bloomberg.com/news/articles/2021-09-10/what-smart-people-get-wrong-about-climate-change-extremes [https://perma.cc/2WHC-Y7JK] (quoting an expert on climate extremes debunking the argument that the simplifying approach taken by some financial regulators is "better than nothing,"—"That is profoundly false, that is just plain wrong.").

I. WHO KNOWS THE FUTURE? THE SUPPLY AND DEMAND OF CLIMATE INFORMATION

A wide array of organizations and individuals produce and consume information about expected "near-to-medium term" climate changes.[48] City governments hire consultants to assess sea-level rise impacts.[49] Insurance companies work with academics to integrate climate into hurricane risk models.[50] Non-profits provide wildfire information to prospective home-buyers.[51] Financial regulators develop banking stress tests.[52] And investment managers partner with climate scientists to analyze the exposure of assets.[53] Scholars and policymakers often use the term "climate services" to label these information providers.[54] The Biden administration defines climate services as "science-based information and products that enhance understanding of climate impacts."[55] This term, however useful, is not

48. What different entities consider "medium-term" can vary substantially. The U.S. SEC's proposed climate risk disclosure rule declines to define the period, leaving it up to reporting companies' discretion. ERNST & YOUNG GLOB. LTD., TECHNICAL LINE: HOW THE CLIMATE-RELATED DISCLOSURE PROPOSALS FROM THE SEC, EFRAG AND ISSB COMPARE 6 (2022). The proposed EU Sustainability Reporting Standards, however, define short-, medium-, and long-term to be "up to five years, more than five years to 10 years and more than 10 years, respectively." *Id.* at 7.

49. ELLIOTT, *supra* note 26, at 119 (detailing New York City's hiring of a private engineering firm to challenge FEMA's re-mapping of risk following Hurricane Sandy).

50. Marie Denoia Aronsohn, *Columbia Researchers Team with Global Firm To Enhance Hurricane Risk Scenarios*, COLUM. CLIMATE SCH. (Nov. 16, 2020), https://news.climate.columbia.edu/2020/11/16/aon-lamont-hurricane-risk-scenarios/ [https://perma.cc/2KCR-76DN]; Jeffrey Ball, *Climate Change Is Hitting the Insurance Industry Hard. Here's How SwissRe Is Adapting*, FORTUNE (Oct. 24, 2019), https://fortune.com/longform/insurance-industry-climate-change-swiss-re-reinsurance/ [https://perma.cc/K84M-PCWZ].

51. Steve Goode, *supra* note 14.

52. Cecilia Bocchio et al., *The ECB 2022 Climate Stress Test: Location Matters for Dutch Mortgages*, MOODY'S ANALYTICS (Apr. 2022), https://www.moodysanalytics.com/articles/pa/2022/the_ecb_2022_climate_stress_test_location_matters_for_dutch_mortgages [https://perma.cc/PQ7W-Z2RM].

53. *See, e.g.*, Antonelli, *supra* note 25.

54. *See, e.g.*, PETER STEGMAIER & ADRIAAN PERRELS, EUR. MKT. CLIMATE SERVS., POLICY IMPLICATIONS AND RECOMMENDATIONS ON PROMISING BUSINESS, RESOURCING, AND INNOVATION FOR CLIMATE SERVICES 70 (2019).

55. *FACT SHEET*, *Biden Administration Makes Climate Information and Decision Tools More Accessible*, *supra* note 41; *see also* OFF. SCI. & TECH. POL'Y ET AL., OPPORTUNITIES FOR EXPANDING AND IMPROVING CLIMATE INFORMATION AND SERVICES FOR THE PUBLIC 6 n.3 (2021) (reporting its definition is modified from the American Meteorological Society's definition of Climate Services); *Climate Services: A Policy Statement of the American Meteorological Society*, AM. METEOROLOGICAL SOC'Y (Sept. 17, 2015) https://www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/statements-of-the-ams-in-force/climate-services1/ [https://perma.cc/FC8B-VYHR].

universally employed by climate service providers themselves. Indeed, a great deal of the supply and demand for physical climate risk analysis comes from the financial sector, where the term "climate services" is not widely used or recognized.[56] Here, "climate analytics" is a common term, and initiatives in "spatial finance" overlap considerably with the climate services world.[57]

The industry is expected to expand rapidly in the coming decades. National securities regulators, including the U.S. SEC, are planning heightened climate risk disclosure requirements.[58] As warming accelerates, and wildfires, droughts, severe storms, and other disasters increase in scale, demand for climate prediction will grow.[59] Adoption of climate services can be seen as a form of climate adaptation. One dilemma, raised by the Society of Adaptation Professionals, is that there are a lot of "adaptation professionals" out there who do not know it yet.[60] Urban planners, developers, engineering consultants for environmental impact statements, insurers, auditors, accountants, homebuyers, investors, industry code and standard setters—the list of roles requiring integration of climate risk assessment goes on. A question currently being contemplated in the United States and abroad is whether the supply of climate services will be sufficient to meet demand, and governments are beginning to explore ways to foster industry growth.[61] This is just one of many questions related to the need for potential regulatory intervention around climate services, along with unequal access, quality control, and others. I turn to these questions in Part II. First, in this Part, I lay out the current landscape of U.S. climate services. Where

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56. The term "spatial finance" is growing in use, though it generally captures the growing adoption of satellites and GIS platforms for analyzing a broad set of location-dependent risk, not merely climate, with emphasis on present-day or near-term risks that can be understood without the use of climate modeling. *See generally* Richard Cooke & Alexander Martonik, *What Is Spatial Finance, and How To Prepare for It*, ENV'T SYS. RSCH. INST. (Mar. 29, 2022), https://www.esri.com/about/newsroom/publications/wherenext/spatial-finance/ [https://perma.cc/T3SL-BGGN]; SPATIAL FINANCE INITIATIVE, STATE AND TRENDS OF SPATIAL FINANCE 2021: NEXT GENERATION CLIMATE AND ENVIRONMENTAL ANALYTICS FOR RESILIENT FINANCE (2021).

57. *See, e.g.*, *Physical Climate Analytics*, PWC, https://www.pwc.co.uk/services/sustainability-climate-change/insights/physical-climate-analytics-tool-powered-by-jupiter-intelligence.html [https://perma.cc/7UZM-N7SX].

58. *See* Press Release, SEC, SEC Proposes Rules To Enhance and Standardize Climate-Related Disclosures for Investors (Mar. 21, 2022), https://www.sec.gov/news/press-release/2022-46 [https://perma.cc/H4BK-Z97X].

59. *The Future of Weather and Climate Services*, WORLD METEOROLOGICAL ORG. (June 9, 2021), https://public.wmo.int/en/media/news/future-of-weather-and-climate-services [https://perma.cc/LS7Z-86QN].

60. *What Is an Adaptation Professional?*, AM. SOC'Y OF ADAPTATION PROS., https://adaptationprofessionals.org/join-us/#adaptation-professional [https://perma.cc/Q7PZ-9H6X].

61. STEGMAIER & PERRELS, *supra* note 54, at 25.

does climate-forecasting data come from and for what purpose? Section A provides a limited overview of the science behind the supply chains of localized climate risk information. Section B describes the rapidly-evolving world of private providers and users of climate risk—with anecdotal examples of how the science is being used to project risks across the financial and corporate worlds.

A. The "Climate Services" Supply Chain

To summarize the state of the science behind pricing many of the climate risks in the timeframe relevant to business decisions and reporting frameworks: it is in progress.[62] Academic climate science has received criticism for focusing on far-off timescales and global scopes, rather than science that is "useable."[63] Here, "usable" means science that can aid decision-making today, including in the financial sector.[64] Practically, it means supporting varying risk appetites and use-cases on timescales ranging from one to thirty-plus years, whether a property insurer pricing an annual rate, a bank assessing a mortgage, or a corporate headquarters pondering a sea wall.[65] Insurers have long been the experts in estimating extreme physical risks over the near term, typically one year.[66] A new type of "climate analytics" consultant caters to the longer-term, working with downstream data produced by global climate models.[67] Outside of the financial world, "useable" climate science has been called "adaptation science," a broad tent

62. An excellent book on the subject: R. SARAVANAN, THE CLIMATE DEMON: PAST, PRESENT, AND FUTURE OF CLIMATE PREDICTION (Cambridge Univ. Press 2022).

63. Sobel, *supra* note 31. This reflects a general sentiment among adaptation scientists and climate impact experts that the mitigation debate has overshadowed adaptation (and arguably helped foster a fixation on global average temperature). INDEPENDENT ASSESSMENT OF UK CLIMATE RISK: ADVICE TO GOVERNMENT FOR THE UK'S THIRD CLIMATE CHANGE RISK ASSESSMENT (CCRA3) 5 (2021) ("But adaptation remains the Cinderella of climate change, still sitting in rags by the stove: under-resourced, underfunded and often ignored."); *see* R. Saravanan, *Hurricane Fed: The New Climate Stress Test for Banks*, METAMODEL BLOG https://metamodel.blog/posts/fed-climate-risk/ [https://perma.cc/A556-MAN2] ("[N]obody lives in 'global-average-land'!").

64. *Id*.

65. Kelly A. Hereid, *Hurricane Risk Management Strategies for Insurers in a Changing Climate*, *in* HURRICANE RISK IN A CHANGING CLIMATE 1, 16–18 (Jennifer M. Collins & James M. Done eds., Springer Int'l Publ'g 2022).

66. Cameron J. Rye et al., *Normative Approach to Risk Management for Insurers*, 11 NATURE CLIMATE CHANGE 460 (2021).

67. *See, e.g.*, *BCG and Jupiter Partner on Climate Risk Analytics*, https://www.consulting.us/news/7804/bcg-and-jupiter-partner-on-climate-risk-analytics [https://perma.cc/CC6F-XW7K].

that includes methods employed by engineers, urban planners, and international development institutions for specific places and uses.[68] When done well, adaptation science grapples with uncertainty, the systemic nature of risk, and expertise from stakeholders and the social sciences.[69] Currently, the private sector and financial regulators are engaged in an early-stage process of combining methods from the "top-down" world of climate scientists and global circulation models with the "bottom-up" world of location-specific approaches of insurers, including their catastrophe models.[70]

The physical risks of climate change can be driven by either acute events or chronic shifts in climate patterns over time.[71] Acute risks include heatwaves, wildfires, floods, landslides, hurricanes, other extreme weather events, and their potential combinations.[72] Chronic risks include those stemming from more gradual shifts in precipitation, sustained ocean and air temperatures, and rising seas.[73] The likelihood that any of these events occur over a certain space and time can be called the "hazard;" there is a great deal of science and statistics behind calculating hazards and how they may be exacerbated by climate change, discussed below. But the pricing of financial risk requires more than an understanding of the hazard. The probabilities of a Category 5 hurricane landfall for example, must be combined with information on exposure (which assets are in the path of the hurricane?) and vulnerability (which assets were built after an upgraded building code was adopted?).[74]

Risk = Hazard x Exposure x Vulnerability[75]

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68. Madeline Ostrander, *The Fervent Debate Over the Best Way to Confront Global Warming*, UNDARK (Aug. 12, 2022), https://undark.org/2022/08/12/the-fervent-debate-over-the-best-way-to-confront-global-warming [https://perma.cc/35HJ-M7AQ].

69. Alberto Arribas et al., *Climate Risk Assessment Needs Urgent Improvement*, 13 NATURE COMMUN'CS 4326 (2022).

70. NICOLA ANN RANGER ET AL., ASSESSING FINANCIAL RISKS FROM PHYSICAL CLIMATE SHOCKS: A FRAMEWORK FOR SCENARIO GENERATION 2627; *see, e.g.*, Andrew Kruczkiewicz et al., *Multiform Flood Risk in a Rapidly Changing World: What We Do Not Do, What We Should and Why It Matters*, 17 ENV'T RSCH. LETTERS 081001 (2022); Giacomo Bressan et al., Asset-Level Climate Physical Risk Assessment is Key for Adaptation Finance (Mar. 6, 2023) (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4062275.

71. BASEL COMMITTEE ON BANKING SUPERVISION, CLIMATE RELATED RISK DRIVERS AND THEIR TRANSMISSION CHANNELS 45 (2021).

72. *Id.*

73. *Id.*

74. See, e.g., Hain et al., *supra* note 22, at 4.

75. Omar-Dario Cardona et al., *Determinants of Risk: Exposure and Vulnerability*, *in* MANAGING THE RISKS OF EXTREME EVENTS AND DISASTERS TO ADVANCE CLIMATE CHANGE ADAPTATION 65 (Christopher B. Field et al. eds., Cambridge University Press 1st ed. 2012).

Exposure is understood by applying the hazard to specific geolocated assets. In the case where the task is to assess a given piece of infrastructure, this step is easy: the location is known.[76] But if an investor wants an assessment of which hard rock mining industry assets are located in future drought regions, or how much of a real estate portfolio will be affected by sea level rise, for example, answering this requires a dataset of where all the mines and buildings are located.[77] Finally, exposure is different from vulnerability, or the assessment of the damage that will result from application of the hazard to the asset.[78] Many commercial climate analytics products make no claims of assessing vulnerability as a component of impact. Instead, they simply offer information on hazard, e.g., a location's fire risk "score," without assessment of how those hazards will manifest in damage or financial costs.[79]

1. Hazards

It is helpful to think of the calculation of climate-influenced hazards as taking place along a multi-step supply chain.[80] The chain begins with what Cortekar et al. have labeled "basic infrastructure," which includes both the observation and collection of weather data, as well as the running of large-scale complex global climate models ("GCMs").[81] At present, the development of GCMs is done exclusively by government-funded institutions that maintain supercomputers and support networks of weather monitoring facilities.[82] The Intergovernmental Panel on Climate Change

76. Or a "market basket," which aims to represent exposures. *See Taking Catastrophe Models out of the Black Box: Understanding, Evaluating, and Using the Best Tools Available for Predicting Risk from Natural Disasters*, MILLIMAN (July 25, 2022) https://www.milliman.com/en/insight/taking-catastrophe-models-out-of-the-black-box [https://perma.cc/6ULV-F38Z].

77. *See, e.g.*, Spatial Finance Initiative, *supra* note 56.

78. David Carlin & Alexander Stopp, *The Climate Risk Tool Landscape: 2022 Supplement*, U.N. ENV'T PROGRAMME, https://www.unepfi.org/wordpress/wp-content/uploads/2022/03/The-Climate-Risk-Tool-Landscape-2022-supplement.pdf [https://perma.cc/BG68-ANV3].

79. *Id. See, e.g.*, Emmanuel M.N.A.N. Attoh et. al., *Making Physical Climate Risk Assessments Relevant to the Financial Sector – Lessons Learned from Real Estate Cases in the Netherlands*, 37 CLIM. RISK. MANAGEMENT 1, 3 (2022) ("However many physical climate risk assessments . . . still focus on the hazard element of the risk assessment."); *Manage Wildfire Risk at the Address Level*, VERISK (2018), https://www.verisk.com/siteassets/intl-canada/downloads/canada-fireline.pdf [https://perma.cc/2B4Y-KUA8].

80. Stegmaier & Perrels, *supra* note 54, at 25; Cortekar et al., *supra* note 13, at 7.

81. Cortekar et al., *supra* note 13.

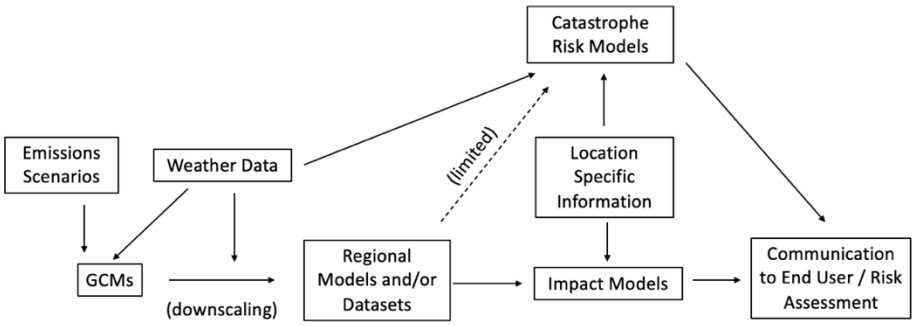
82. *Id.* at 7–8; Nejat Anbarci et al., *Population and Income Sensitivity of Private and Public Weather Forecasting*, 41 REG'L SCI. AND URB. ECON. 124, 125 (2011).

("IPCC") reviews and synthesizes GCMs in an ensemble of models known as the Coupled Model Intercomparison Project ("CMIP").[83] The latest meta-model output, CMIP6, drew on more than 100 climate models from sixteen countries plus Europe.[84] These models all produce information on long-term physical climate parameters, like temperature and precipitation changes, based on given emissions-pathway inputs.[85]

83. Veronika Eyring et al., *Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) Experimental Design and Organization*, 9 GEOSCIENTIFIC MODEL DEV. 1937, 1938 (2016). CMIP does not assess the "skill" of models when including them in the ensemble (i.e., they do not remove the models that are the least effective at forecasting), a choice that has received criticism. Fiedler et al., *supra* note 25, at 87. "Coupled model" refers to GCMs that include both atmospheric and ocean models that interact. Over decades, models have included more environmental processes and feedback loops, at a higher resolution. ADAM TERANDO, U.S. GEOLOGICAL SURV., USING INFORMATION FROM GLOBAL CLIMATE MODELS TO INFORM POLICYMAKING—THE ROLE OF THE U.S. GEOLOGICAL SURVEY 8 (2020).

84. Shipra Jain et al., *Are We at Risk of Losing the Current Generation of Climate Researchers to Data Science?*, 3 AGU ADVANCES 1 (2022).(noting that CMIP6 encompasses "~120 models from ~50 modeling groups, [and] ~20 to 40 petabytes (PB) of output data"). The U.S. models were produced by the Department of Energy ("DOE"), the National Oceanic and Atmospheric Administration ("NOAA"), NASA, and the National Center for Atmospheric Research. Gavin A. Schmidt et al., *Practice and Philosophy of Climate Model Tuning Across Six U.S. Modeling Centers,* 10 GEOSCIENCE MODEL DEV. 3207, 3211 tbl. 1 (2017).

85. The IPCC relies on these standardized pathways for intercomparison between research projects. "Representative Concentration Pathways" ("RCPs") are named after the radiative forcing produced by the modeled scenario in 2100, i.e., RCP 8.5 projects an atmosphere with a radiative forcing of 8.5 W/m2 at the end of the century. Newer "Shared Socioeconomic Pathways" ("SSPs") were developed to represent policy assumptions and development patterns more granularly. The SSPs map how each of the RCP paths could be achieved under five alternative narrative futures. Zeke Hausfather, *Explainer: How 'Shared Socioeconomic Pathways' Explore Future Climate Change*, CARBON BRIEF (Apr. 19, 2018), https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change/.



Simplified climate services supply web[86]

Global climate models provide simulations of climate changes on a scale that is too large to be useful for assessing acute risks to specific buildings, or even cities—the models output information on a grid with around sixty miles between coordinates.[87] Scientists are moving toward higher-resolution GCMs, but a significant limitation to this approach is the computational power and time required for model runs as the data becomes more and more granular, and thus more cumbersome.[88]

A common method for translating forecasted effects from current global models into local-scale predictions is "downscaling." Scientists either use dynamic downscaling, which links regional models with global models, or—more commonly—statistical downscaling, which uses historic weather data from a specific area to calibrate and apply the global model results.[89] Downscaling can lead to better predictions, but there are tradeoffs between different approaches (between global coverage versus a more precise method

86. Inspired by representations by Cortekar et al., *supra* note 13 and Oriana Chegwidden, et al., *Open Data and Tools for Multiple Methods of Global Climate Downscaling*, CARBONPLAN, https://carbonplan.org [https://perma.cc/43ML-LBG9].

87. *See e.g.*, Chegwidden, et al., *supra* note 86.

88. *See High-Resolution Atmosphere Modeling*, GEOPHYSICAL FLUID DYNAMICS LAB'Y, https://www.gfdl.noaa.gov/high-resolution-atmosphere-modeling/ [https://perma.cc/98JX-J9T5]; R. Saravanan, *What to Expect When You're Expecting a Better Climate Model*, METAMODEL BLOG (Jul. 13, 2022), /posts/model-expectations/.

89. *Climate Model Downscaling*, GEOPHYSICAL FLUID DYNAMICS LAB'Y, https://www.gfdl.noaa.gov/climate-model-downscaling/; COPERNICUS CLIMATE CHANGE SERV., WHAT IS STATISTICAL AND DYNAMICAL DOWNSCALING?, https://climate.copernicus.eu/sites/default/files/2021-01/infosheet8.pdf [https://perma.cc/8FG7-NLKV].

for certain regions, for example) such that evaluating and working with downscaled data requires significant skill.[90]

In general, downscaled GCMs may not be the ideal tool for predicting certain localized climate-related effects for financial actors.[91] GCMs are designed for predicting long-term trends in global circulation and changing averages.[92] Scientists are becoming increasingly confident about the ability of climate models to predict regional increased frequency and intensity of rainfall and drought, and longer and more intense heat waves, though the certainty can vary depending on the region.[93] At present, climate models are limited in their ability to predict extremes, including extreme temperature events, like anomalous heatwaves, polar vortexes, and other low-probability high-impact weather events, like extreme precipitation.[94] Another way to say this is that they struggle to capture the end-tails of probability distributions.[95] This is for a variety of reasons related to the fact that climate models are not weather models and, as journalist Kate Mackenzie has explained, "weather

90. *See, e.g.*, Josh Hacker, *CORDEX: Assessing Its Progress, Roles, and Challenges* (Jupiter Intelligence 2021); Evan Kodra, *"Downscaling": Climate Modeling's Distracting Vaporware – RisQ*, https://www.risq.io/2021/04/downscaling-climate-modelings-distracting-vaporware/.

91. *See, e.g.*, MACKENZIE L. BLANUSA ET AL., THE ROLE OF INTERNAL VARIABILITY IN GLOBAL CLIMATE PROJECTIONS OF EXTREME EVENTS 17 (2022) ("[P]ast observations (if available for a long enough period) can provide almost as accurate a picture of future extreme occurrences as even the best possible next-generation climate models, for most regions."); Ben Dyson, *Catastrophe Modelers Are Tackling Climate Change amid Pressure from Insurers*, S&P GLOB. MKT. INTEL. (Nov. 15, 2019), https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/catastrophe-modelers-are-tackling-climate-change-amid-pressure-from-insurers-55509472 ("Climate change may be visible on a global scale, but catastrophe modelers require evidence at the country, regional or even more local level. . . . ").

92. Alan Buis, *Study Confirms Climate Models Are Getting Future Warming Projections Right*, NASA, CLIMATE CHANGE: VITAL SIGNS OF THE PLANET (Jan. 9, 2020), https://climate.nasa.gov/news/2943/study-confirms-climate-models-are-getting-future-warming-projections-right

93. Sonia Senevirante & Xuebin Zhang, *Weather and Climate Extreme Events in a Changing Climate*, *in* CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP ITO THE SIXTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 1513 (Cambridge University Press 2021). Robert McSweeney, *Explainer: What the New IPCC Report Says about Extreme Weather and Climate Change*, CARBON BRIEF (Aug. 10, 2021), https://www.carbonbrief.org/explainer-what-the-new-ipcc-report-says-about-extreme-weather-and-climate-change

94. Pitman et al., *supra* note 23.

95. *See, e.g.*, Jesse Norris et al., *Evaluation of the Tail of the Probability Distribution of Daily and Subdaily Precipitation in CMIP6 Models*, 34 J. CLIMATE 2701 (2021); Sabine Hossenfelder, *Do Climate Models Predict Extreme Weather?*, BACKRE (ACTION) (Jan. 8, 2022), http://backreaction.blogspot.com/2022/01/do-climate-models-predict-extreme.html [https://perma.cc/JAL3-SG3J] (providing a useful public-oriented video explainer).

events are relatively small, local phenomena."[96] For one, weather patterns develop on a scale not granularly represented in a global model, and can depend on specific local features, like clouds or topography.[97] For another, scientists calibrate and test model accuracy using paleoclimate datasets constructed from ice cores and tree rings—datasets that may well capture long-term historical trends but not specific local weather events.[98] And our historical record of extreme events is limited.[99] Finally, there is natural variability in the climate system. Phenomena like El Niño and longer, decadal, oscillations mean that weather events in individual years may not neatly follow the trend projections of climate models, even if their long-term outputs of changing averages are correct.[100] There is increasing interest in improving GCM forecasts for the nearer term, but some experts have cautioned that it would require unrealistic advances in computing technology for climate models to operate at weather-scale resolution anytime soon.[101]

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96. Kate Mackenzie, *Companies Are Rushing To Pinpoint Climate Risks, But It's Often Impossible*, BLOOMBERG (Feb. 12, 2021), https://www.bloomberg.com/news/articles/2021-02-12/companies-are-rushing-to-pinpoint-climate-risks-but-it-s-often-impossible?sref=GBEdnt3o#xj4y7vzkg [https://perma.cc/WF3G-RRRT]; *see also* TERANDO ET AL., *supra* note, at 16 (explaining that a "skillful climate model [is expected to] reproduce the observed past, present, or future *climate* (that is, the statistical properties of meteorological variables) . . . but there is no equivalent expectation for a skillful climate model to be able to reproduce the observed past, present, or future day-to-day *weather*").

97. TERANDO ET AL., *supra* note, at 16; *see, e.g.*, Van Oldenborgh et al., *Attributing and Projecting Heatwaves Is Hard: We Can Do Better*, 10 EARTH'S FUTURE 1, 8 (2022) (explaining that GCMs capture "large-scale changes in mean temperature" well but that "heatwaves on the scales people experience them are strongly influenced by [local variables like] land surface, vegetation, irrigation, and urbanization" which are not captured at the granularity of current models).

98. Robert McSweeney, *Factcheck: Are Climate Models Wrong on Rainfall Extremes?* CARBONBRIEF (Apr, 7, 2016) https://www.carbonbrief.org/factcheck-are-climate-models-wrong-on-rainfall-extremes/ [https://perma.cc/9HGK-DX9L].

99. Mackenzie, *Companies Are Rushing To Pinpoint Climate Risks, supra* note 96; Sjoukje Philip et al., *A Protocol for Probabilistic Extreme Event Attribution Analyses*, 6 ADVANCES IN STAT. CLIMATOLOGY, METEOROLOGY & OCEANOGRAPHY 177 (2020) (explaining that modeling droughts and floods "is often challenging due to lack of long-term observational data," a mismatch in horizontal scale between global climate models and the event of interest, and a mismatch in timescale of observational data, i.e., trying to model a flash flood event from an intense hour of rainfall using on a record of daily precipitation).

100. Flavio Lehner et al., *Partitioning Climate Projection Uncertainty with Multiple Large Ensembles and CMIP5/6*, 11 EARTH SYST. DYNAM. 491 (2020).

101. Gavin Schmidt, *Mmm-k Scale Climate Models*, REALCLIMATE (June 25, 2022), https://www.realclimate.org/index.php/archives/2022/06/mmm-k-scale-climate-models Saravanan, *supra* note 88.

Some near-term climate impacts are easier to model than others—there is more certainty around sea-level rise projections, for example, than drought.[102] This is in part due to the relative simplicity of the physical processes behind sea-level rise as compared to the drivers of regional drought (although there are indeed uncertainties), and in part due to the fact that there is "significant inertia in the physical processes" behind the contributors to sea level rise.[103] Ice sheet melt occurs on decadal time scales and will continue in the near-term regardless of future emissions pathways.[104]

Therefore, the reliability of any climate model forecast depends on the information being sought: 1) temporal resolution (Are you asking about the chances of a flood occurring over a year or over a decade?); 2) spatial resolution (Are you asking about precipitation changes for New England or Boston?); 3) time-horizon (Are you asking about sea-level rise in five years or fifty?); 4) phenomena itself (Are you asking about wildfires or temperature rise?) and 5) location (Are you asking about the impact to a factory in Michigan or Tanzania?).[105] In the longer-term, one of the largest uncertainties stems from the unpredictability of human behavior—at what speed will society reduce emissions?[106] In the nearer term, the biggest uncertainties generally come from uncertainties in the model itself, and natural climate variability.[107] Some uncertainties are very difficult to resolve, like tipping points (just when a certain ice sheet will fall into the ocean is hard to pinpoint).[108]

Uncertainty typically increases as you narrow the geographic location or time increment, you forecast further out in time, or you examine more complex phenomena. This means that physical risk modeling for the hazards and timeframes that are relevant for public and private sector decision making

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102. *Cf.* Basis, *supra* note 39. *See, e.g.*, Theodore Shepherd, *Storyline Approach to the Construction of Regional Climate Change Information*, 475 PROC. R. SOC. A 1-2 (2019); Jeremy Bassis, *Quit Worrying About Uncertainty in Sea Level Projections*, EOS (Nov. 30, 2021), https://eos.org/opinions/quit-worrying-about-uncertainty-in-sea-level-projections [https://perma.cc/5ZAP-6MC5].

103. Terando, *supra* note 83, at 15.

104. *Id.*

105. Xianfu Lu, *The Use of Climate Information for Climate Resilience and Adaptation: Current Practices* (Mar. Elfatih Eltahir, *Climate Models*, MASS. INST. OF TECH. (Jan. 8, 2021), https://climate.mit.edu/explainers/climate-models#:~:text=Climate%20models%20are%20computer%20programs,the%20climate%E2%80%94under%20different%20conditions [https://perma.cc/R3CN-L2HH].

106. Terando, *supra* note 83, at 8.

107. Ed Hawkins & Rowan Sutton, *The Potential to Narrow Uncertainty in Regional Climate Predictions*, 90 OF THE METEOROLOGICAL 1095 (American Meteorological Society Aug. 2009); Lehner et al., *supra* note 100.

108. Seaver Wang et al., *Mechanisms and Impacts of Earth System Tipping Elements*, 61 REVIEWS OF GEOPHYSICS e2021RG000757 (2023).

is both a work in progress and retains fundamental uncertainties that cannot be modeled around.[109]

2. Impact Models: Exposure & Vulnerability

While near-term sea-level rise can be forecast with some certainty, understanding how sea-level rise will manifest in a particular geography requires detailed data inputs to get correct.[110] Predicting which houses in a neighborhood might be exposed to flooding requires geographic data like granular elevation, land surface type, tidal behavior, and more.[111] And knowing just how damaging flooding will be requires even more data, like construction material and adaptation steps taken.[112] These impact models, which estimate things like potential loss damage following a hurricane, or the effect of increased temperature on crop yields, sit downstream of the GCMs and downscaled models.

Current private sector and financial regulator approaches to modeling impacts can be very roughly broken down into either "top-down" or "bottom-up" modeling frameworks.[113] A top-down model takes the outputs of global climate models ("GCM") and links them to projected changes in the economy. The top-down approach, for example, may model impacts on crop yields from regional forecasted drought, or the change to GDP from decreased labor productivity from hotter days. The classic application of the top-down approach is understanding the macroeconomic and broad regional

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109. Martin Bertogg, *Tackling the Here and Now: Why We Need To Rethink Our Natural Catastrophe Risk Models*, SWISS RE (Apr. 7, 2021), https://www.swissre.com/risk-knowledge/mitigating-climate-risk/rethinking-our-risk-models.html [https://perma.cc/8JDQ-CGLH]; SARAVANAN, *supra* note 62.

110. Nevertheless, "deep uncertainty" as to sea level rise remains. *See, e.g.*, James Doss-Gollin & Klaus Keller, *A Subjective Bayesian Framework for Synthesizing Deep Uncertainties in Climate Risk Management*, 11 EARTH'S FUTURE 1, 1 (2023).

111. *See, e.g., Climate Natural Disaster Risk Listening Session,* FED. HOUSE FIN. AGENCY, at 10:15 (Jan. 19, 2021), https://www.fhfa.gov/Videos/Pages/FHFA-Public-Listening-Session-on-Climate-and-Natural-Disaster-Risk-Management-at-the-Regulated-Entities.aspx [https://perma.cc/5ML9-B8X6] (transcript available at https://www.fhfa.gov/Media/Documents/ClimateNaturalDisasterRisk-ListeningSession-transcript.pdf [https://perma.cc/U66F-UPSE]) (using high tide gauge data, elevation data, sea level projections and property data from Zillow to predict flooding damage to homes).

112. *Id.* at 1:17:37.

113. Various models can combine both top-down and bottom-up aspects, and indeed this is the project. *See, e.g.*, Manuel Pulido-Velazquez et al., *A Top-Down Meets Bottom-Up Approach for Climate Change Adaptation in Water Resource Systems*, CLIMATE ADAPTATION MODELLING 149 (2022). Naqvi, A., Monasterolo, I., *Assessing the cascading impacts of natural disasters in a multi-layer behavioral network framework*, SCI. REP. 11, 20146 (2021).

effects of chronic changes, e.g., temperature over the next decades.[114] Conversely, the "bottom-up" approach, historically employed by insurance companies and engineers, was developed to address acute risk in a specific geography at a granular scale.

An Integrated Assessment Model ("IAM") is one type of impact model widely used by financial actors and policymakers.[115] IAMs aim to link socioeconomic processes and dynamics to climate change. Early "cost-benefit" IAMs began being used in U.S. climate policy in the 1990s, particularly in conversations around taxation and the "social cost of carbon."[116] These simple cost-benefit models are "highly aggregated," in contrast to the more detailed "process-based" IAMs that generate the transition scenarios produced by both the NGFS and the IPCC.[117] Most IAMs used for calculating physical risk, however, employ a "damage function" representing the relationship between global (and sometimes regional) average temperature rise and socioeconomic metrics such as GDP.[118] The relationship between socioeconomic or health outcomes and temperature is often based solely on historic data, e.g., economies are observably less "productive" in hotter climates so that relationship is applied to the future.[119]

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114. *See, e.g.*, *"Which models?" What Methodological Choices Went into the IWG Numbers?*, THE COST OF CLIMATE POLLUTION, https://costofcarbon.org/faq/what-methodological-choices-went-into-the-iwg-numbers [https://perma.cc/Q7BV-D9CG].

115. There are several different kinds of IAMs, with varying complexities and uses. *See, e.g.*, SARAH BREEDEN & FRANK ELDERSON, GUIDE TO CLIMATE SCENARIO ANALYSIS FOR CENTRAL BANKS AND SUPERVISORS 23 (2020), https://www.ngfs.net/sites/default/files/medias/documents/ngfs_guide_scenario_analysis_final.pdf [https://perma.cc/VNY9-XTQ3] (surveying five types of IAMs, including "cost-benefit" and "process-based"); Simon Evans & Zeke Hausfather, *Q&A: How 'Integrated Assessment Models' Are Used To Study Climate Change*, CARBON BRIEF (Oct. 2, 2018), https://www.carbonbrief.org/qa-how-integrated-assessment-models-are-used-to-study-climate-change/ [https://perma.cc/A9U6-7KNB].

116. For example, the widely used DICE—first published by William Nordhaus in 1992 is meant to calculate the "optimal" emissions policy, balancing the costs of regulation against the benefits of avoided damages. Samuel Randalls, *Optimal Climate Change: Economics and Climate Science Policy Histories (from Heuristic to Normative)*, 26 OSIRIS 224 (2011).

117. Lisette van Beek et al., *Anticipating Futures through Models: The Rise of Integrated Assessment Modelling in the Climate Science-Policy Interface since 1970*, 65 CHANGE 102191 (Nov. 2020). See also, Simon Evans & Zeke Hausfather, *supra* note 115. (distinguishing between "simple [cost-benefit] and complex IAMs").

118. Anselm Schultes et al., *Economic Damages from On-Going Climate Change Imply Deeper near-Term Emission Cuts*, 16 ENVIRON. RES. LETT. 104053 (2021).

119. The damage function that underlies the NGFS physical risk scenarios, for example, calculates the historic relationship between temperature deviations and productivity at the regional level (without explaining why we would expect this relationship to hold in the future). Matthias Kalkuhl & Leonie Wenz, *The Impact of Climate Conditions on Economic Production. Evidence from a Global Panel of Regions*, 103 J. 102360 (Sep. 2020). *See also*, Irene Monasterolo

But mounting critiques argue these methodological assumptions—e.g., assuming a simple relationship between average global temperature projections and localized climate impacts, or holding historic relationships between events and damages constant in the future—are deeply flawed.[120] Average global warming can lead to increased rainfall in certain places and decreased in others.[121] And these models ignore many categories of significant physical climate impacts, including compounding and cascading risks.[122]

These omissions and assumptions are made, in part, because an IAM is a much simpler model than a GCM. Some can be run in Excel rather than requiring a government-run supercomputer. And working with a range of global temperature data is an order of magnitude simpler than working with a massive amount of granular spatial data downloaded from CMIP. Working with that data, downscaled or not, and maintaining the uncertainty bars around CMIP projections, requires significant time and computing resources. There is appeal, therefore, in relying on cheaper models, particularly when there is little expertise in the industry to evaluate methods. One climate analytics executive recently complained to Bloomberg that his company had "been offered project fees that don't even cover the cost of firing up the cloud servers, but someone did the job. And that becomes their [climate risk] disclosure."[123] This is potentially a serious concern if private climate services fail to understand (or hide) the limitations of how GCM outputs can be used.

Insurance companies have long been in the business of modeling extreme weather events over the near-term—e.g., the following year—and for this they use a bottom-up approach. Insurers typically approach risks on a peril-specific basis, with different approaches potentially undertaken for hurricane

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et al., *The Good, the Bad and the Hot House World: Conceptual Underpinnings of the NGFS Scenarios and Suggestions for Improvement* (Banco de España, Working Paper No. 2302, 2023)

120. Irene Monasterolo et al., *The Good, the Bad and the Hot House World: Conceptual Underpinnings of the NGFS Scenarios and Suggestions for Improvement*, No. 2302, 2302 (Banco de España Feb. 2023); Pitman et al., *supra* note 24. *See also*, BREEDEN & ELDERSON, *supra* note 115 (noting that "variations of [damage] functions are still being used widely but lack a proper empirical foundation, and there is wide agreement that they underestimate economic damages").

121. Pitman et al., *supra* note 24.

122. RANGER ET AL., *supra* note 24. Work on more complex IAMs that better integrate physical risk is ongoing, though those at the macro scale continue to fail to capture the immense uncertainty in climate science and societal pathways. See, e.g., Hiroko Oura et al., *Bank Stress Testing of Physical Risks under Climate Change Macro Scenarios: Typhoon Risks to the Philippines*, 2022 IMF WORKING PAPERS 1 (Aug. 2022). (constructing a bottom-up damage function of typhoon risk in the Philippines, an alternative to the "arbitrary damage functions used in IAMs").

123. Mackenzie, *supra* note 96.

risk versus wildfire risk, for example.[124] The simplest bottom-up approach is to rely solely on the recent historical record of an event.[125] This actuarial approach is mandated for California wildfire insurance, where providers are required to set rates based on the past twenty years of wildfire loss data (over protest that climate change requires more forward-looking metrics).[126] But for other perils, in other markets, a more complex bottom-up approach is catastrophe ("cat") modeling.[127] Cat models were built precisely for the purpose of pricing perils in cases where the historic record was recognized as insufficient.[128] This is the case for low-probability, high-loss events, like high magnitude earthquakes and Category 5 hurricanes hitting highly populated areas—events that would be underrepresented in the record regardless of climate change. Cat models were adopted widely after Hurricane Andrew struck the Florida coast in 1992, bankrupting eleven insurance companies and scaring the industry.[129]

Catastrophe models for pricing hurricane and earthquake risk have now been used by insurers and accepted by regulators for decades.[130] Unlike global climate models, cat models were developed to capture localized extreme events, and thus have been highly developed in the California and Florida markets.[131] They are dependent on rich and granular exposure datasets, and include considerations like land use and density to produce a

124. Hurricane models are broken down again into modeled sub-perils. Hereid, *supra* note 65.

125. *Taking Catastrophe Models out of the Black Box*, *supra* note 76.

126. *See, e.g.*, Rex Frazier, *California's Ban on Climate-Informed Models for Wildfire Insurance Premiums*, 48 ECO. L. CURRENTS 24 (2021) (discussing the advantages of using cat models and highlighting concerns, including whether actuaries are trained to properly use and interpret cat models); *Report from California Insurers Calls for More Freedom to Use Wildfire Catastrophe Models*, INSURANCE J., https://www.insurancejournal.com/news/west/2022/11/29/696876.htm The shift from actuarial to catastrophe methods also enables and incentivizes the collection of granular data that can capture differences in risk between homes, as opposed to more regional-based methods.

127. Dyson, *supra* note 91; *Risky Business: Modeling Catastrophes*, EARTH MAG. https://www.earthmagazine.org/article/risky-business-modeling-catastrophes

128. *Taking Catastrophe Models out of the Black Box*, *supra* note 76.

129. Michael Lewis, *In Nature's Casino*, YORK TIMES (Aug. 26, 2007), https://www.nytimes.com/2007/08/26/magazine/26neworleans-t.html. [https://perma.cc/7CWP-S832] (excellent longform piece profiling Karen Clark, who pointed out that insurers were ignoring the rare but extreme hurricanes captured in the long historic record, but was ignored until Andrew: "This one woman really created the method for valuing this risk").

130. *Id.*

131. *See* MARYAM GOLNARAGHI, GENEVA ASS'N, MANAGING PHYSICAL CLIMATE RISK: LEVERAGING INNOVATIONS IN CATASTROPHE RISK MODELLING 7 (2018).

monetized output such as "annual average loss."[132] They typically do this using statistical analysis of historic weather data applied to current circumstances—an approach that may capture recent climate change, but in its simplest form ignores anticipated changes from the effect of increased temperatures on weather extremes.[133] This is in part because cat models are used to price risks over the relatively short length of an insurance contract.[134] Models may include relevant climate change impacts that can be observed today; a hurricane, for example, is likely more destructive than the same intensity hurricane twenty years ago, in part due to higher storm surge from sea-level rise.[135] Increasingly, the models and approaches used by insurers explicitly consider the outputs of GCMs and other climate science, with debate over whether they are sufficiently capturing the increased risk.[136] Beyond hurricanes, catastrophe models for other perils, like wildfire and floods are "less mature," but there has been rapid private sector activity in developing their uses and pushing for regulatory acceptance.[137]

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132. *See Navigating Climate Change Through Climate Risk Modeling*, AON, https://insights-north-america.aon.com/total-cost-of-risk/navigating-climate-change-through-climate-risk-modeling [https://perma.cc/PKT8-WDK8] (noting that cat models are produced by cross-disciplinary teams to help predict potential financial impact).

133. LLOYD'S, CATASTROPHE MODELLING AND CLIMATE CHANGE 4 (2014); Bertogg, *supra* note 109.

134. *See* GOLNARAGHI, *supra* note 131, at 7 (noting that cat models have "transformed the (re)insurance industry's capacity to assess, price and manage risks of extreme events").

135. LLOYD'S, *supra* note 133, at 22. ("The approximately 20 centimeters of sea-level rise [in lower Manhattan] . . . increased [Hurricane] Sandy's ground-up surge losses by 30% in New York alone."). Population growth is also a large driver of increased risk.

136. *Compare RMS Global Catastrophe Model Leader Launches First Climate Change Models, Enabling New Risk Insights*, RMS (May 5, 2021), https://www.rms.com/newsroom/press-releases/press-detail/2021-05-05/rms-global-catastrophe-model-leader-launches-first-climate-change-models-enabling-new-risk-insights [https://perma.cc/HRF8-V6NW] (advertising a catastrophe model that "[c]onfidently communicate[s] acute physical risks posed by climate change to all stakeholders"), *with* Stefan Wolf Stärtzel et al., *Uniting Catastrophe and Climate Models To Enhance Risk Management in a Warming World*, AON, https://www.aon.com/data-analytic/tech-perspectives/20200921-tp-climate-cat-model-eval [https://perma.cc/7QUH-78UL] (arguing that climate risk models are more forward-looking than cat models), *and* Steve Evans, *Cat Models Don't Properly Reflect Climate Change: RenRe CEO O'Donnell*, ARTEMIS (July 26, 2022), https://www.artemis.bm/news/cat-models-dont-properly-reflect-climate-change-renre-ceo-odonnell/ [https://perma.cc/EA3G-W2XV].

137. *Taking Catastrophe Models out of the Black Box*, *supra* note 76.

3. Risk Communication

Downstream of the impact models, finally, are products and services that communicate climate information to end users. This information can be translated in the form of financial risk, with terms like "expected loss"—but more commonly the information is communicated at the hazard level: a "fire score" or "hazard rating," for example, that is quantitative but not necessarily linked to any particular asset.[138] These tools and metrics may be provided by consultancy services or a non-profit's online flood mapping tool. The upstream generation of climate information—the product of large amounts of observational data and computing power—is almost exclusively generated by public providers.[139] Most private climate services work downstream, downscaling GCMs, developing impact models for particular clients and geographies, assembling and licensing geospatial databases, and communicating climate risk. The landscape is also shifting, as changes in technology and business models encourage private businesses to enter farther upstream into the observation and data collection space.[140]

B. The Business of Climate Risk

Forecasts of climate-related risks are increasingly being incorporated in a wide range of private-sector decision-making, including underwriting, credit rating, securities valuation, portfolio construction, infrastructure resilience, and operations management. Climate analytics start-ups and established catastrophe modelers have been attractive acquisition targets—part of a broader trend in the ESG data industry.[141] Andreas Dimmelmeier tracked a cascade of recent mergers resulting in forty-eight ESG providers consolidating into five industry leaders: Moody's, MSCI, Morningstar, ISS, and S&P.[142] The trend is reflected in acquisitions of analytics companies focused primarily on physical risk. A 2021 UN Environment Programme

138. *Charting a New Climate: State-of-the-Art Tools and Data for Banks to Assess Credit Risks and Opportunities from Physical Climate Change Impacts* (UNEP-FI-TCFD).

139. *See* Cortekar et al., *supra* note 13, at 7; Stegmaier & Perrels, *supra* note 54, at 44.

140. Adrian Perrels, *Weather and Climate Services*: *An Increasing Range of Choice for the Public and Private Sectors*, WORLD METEOROLOGICAL ORG. (2019), https://public.wmo.int/en/resources/bulletin/weather-and-climate-services-increasing-range-of-choice-public-and-private [https://perma.cc/K8YE-KLNT].

141. Declan Harty & Maria Tor, *Consolidation Among ESG Data Providers Continues amid COVID-19 Pandemic*, S&P GLOB. MKT. INTEL. (Apr. 29, 2020), https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/consolidation-among-esg-data-providers-continues-amid-covid-19-pandemic-58306410 [https://perma.cc/YA2V-XYQT] ("It does seem to be moving toward an oligopoly.").

142. Dimmelmeier, *supra* note 17, at 8.

report cataloged fourteen leaders in financial sector physical risk analysis.[143] The list included The Climate Service, bought by S&P; Four Twenty Seven and RMS, both bought by Moody's; [144] Acclimatise, bought by Wills Towers Watson; South Pole bought by ISS; Planetrics acquired by McKinsey; Rhodium, whose physical risk model was bought by asset manager BlackRock;[145] and Carbon Delta, whose "Climate VaR" model was bought by MSCI.[146]

As many of these financial services firms provide products to a range of clients, it can be challenging to track just how climate data produced by recent acquisitions are used throughout a range of products. Moody's and S&P are both ratings agencies and sellers of climate risk data. S&P additionally assembles and licenses financial indexes that asset managers use for investment decisions and benchmarks.[147] Four Twenty Seven, now rebranded as Moody's ESG Solutions, sells a dataset of physical climate risks at the zip-code level, marketed to banks, insurers, and asset managers for their "risk management strategies."[148] The methodology behind the scores is not

143. Paul Smith, *The Climate Risk Landscape*, U.N. ENVIRONMENT PROGRAMME (Feb. 2021), https://www.unepfi.org/wordpress/wp-content/uploads/2021/02/UNEP-FI-The-Climate-Risk-Landscape.pdf [https://perma.cc/4L8S-RQPQ].

144. *News: Moody's Acquires Majority Stake in Four Twenty Seven, Inc., a Leader in Climate Data and Risk Analysis*, MOODY'S (July 24, 2019), https://s28.q4cdn.com/193705676/files/doc_news/archive/f5ab9b57-7add-4e9f-ade3-7e8dfb2d6d78.pdf [https://perma.cc/VLQ6-SGBY]; *Our Publications*, FOUR TWENTY SEVEN, https://427mt.com/ [https://427mt.com/].

145. *BlackRock Partners with Rhodium on Climate Analytics*, BLACKROCK, https://www.blackrock.com/us/individual/about-us/blackrock-rhodium-partner-on-climate-analytics [https://perma.cc/MN6M-SXA2].

146. Leading consultancies that remain independent and unacquired include U.S. Jupiter Intelligence and Australian XDI, which has partnered with Baringa Partners. *See, e.g.*, *Legal & General Adopts Baringa's Breakthrough Climate Change Scenario Model for Financial Services*, BARINGA (Mar. 12, 2020), https://www.baringa.com/en/insights-news/news/legal-general-adopts-baringas-breakthrough-climat/ [https://perma.cc/3KZX-8CKM].

147. S&P Global's "Paris-Aligned & Transition Indices" weight assets based on a Trucost physical risk score (along other metrics like emissions alignment) but it is unclear how this score is generated. S&P Dow Jones Indices, *S&P Paris-Aligned & Climate Transition (PACT) Indices Methodology* (Feb. 2023).

148. *Moody's ESG Solutions Expands Physical Climate Risk Scores to Sub-Sovereigns*, BUSINESS WIRE (Oct. 7, 2021), https://www.businesswire.com/news/home/20211007005579/en/Moody%E2%80%99s-ESG-Solutions-Expands-Physical-Climate-Risk-Scores-to-Sub-Sovereigns [https://perma.cc/6SFV-HUUE] (finding that twenty-six percent of U.S. zip codes are "highly exposed to floods"); *see also* Liz Najman, *US Semiconductor Hubs Need to Address Physical Climate Risks to Sustain Investment*, MOODY'S (Sept. 15, 2021), https://esg.moodys.io/insights-analysis-reports/us-semiconductor-hubs-need-to-address-physical-climate-risks-to-sustain-investment [https://perma.cc/Z3VY-QUAN] (highlighting physical climate risks to U.S. domestic semi-conductor industry).

disclosed, but in the past, Four Twenty Seven generated similar scores by combining downscaled CMIP data with other data on factors like water stress, historic hurricanes, and detailed flood modeling.[149] These scores are meant to indicate hazard only, they are not prepared for a particular asset or use case.[150]

A range of new start-ups focus on satellites and remote sensing technology for producing granular spatial datasets.[151] As investors increasingly realize that understanding companies' climate risk requires knowing where assets and supply chains are physically located, there has been a large demand for datasets enabling "spatial finance."[152] Satellite data can be paired with artificial intelligence and machine learning techniques to develop new approaches to modeling wildfire, geomapping industrial assets, and developing detailed exposure datasets.[153] Startup Cervest pitches that their platform allows companies to understand and disclose the climate risks faced not only by their own assets, but those that "they rely on throughout their supply chain" with 500 million discoverable global assets.[154] Unilever has partnered with Google's satellite landcover tracking to monitor deforestation in its supply chain. "AI-powered real estate valuation platform" Geophy used 427 data to assess the climate exposure of real estate investment

149. *Measuring What Matters: A New Approach to Assessing Sovereign Climate Risk*, MOODY'S (Dec. 3, 2020, 3:23 AM), https://www.businesswire.com/news/home/20201203005359/en/ [https://perma.cc/URY7-D8KV].

150. DUHRA & MASOOD, *supra note* 25. ("Over 2.8 million physical assets, including offices and factories, have been assessed against seven different types of physical risks including hurricanes and heatwaves."); *see also* S&P DOW JONES INDICES, S&P PARIS-ALIGNED & CLIMATE TRANSITION (PACT) INDICES METHODOLOGY (2022), https://www.spglobal.com/spdji/en/documents/methodologies/methodology-sp-paris-aligned-climate-transition-pact-indices.pdf [https://perma.cc/YL3D-MQ3U].

151. *What is Climate Fintech and Why Do VCs Love It so Much?*, SIFTED, https://sifted.eu/articles/what-is-climate-fintech/ (calculating that in the first half of 2022, 385 Euros were raised by climate risk management (or "climate intelligence") startups, including London based Cervest and Climate X, which provide climate risk projections and ratings, and Lisbon-based Tesselo "which uses satellite imagery and AI to estimate the risk and impact of wildfires.")

152. Ben Caldecott, *Spatial Finance and the Future of ESG* (Nov. 2019). ("mainstream geospatial capabilities enabled by space technology and data science into financial decision-making globally").

153. MATTHEW CARTER ET AL., ASSET-LEVEL DATA FOR CEMENT AND SPATIAL FINANCE USE CASES FOR THE CEMENT AND STEEL SECTORS 4, https://sa.catapult.org.uk/wp-content/uploads/2021/07/Asset-level-Data-Use-Cases-for-the-Cement-and-Steel-Sectors.pdf [https://perma.cc/GU6V-ANEZ] (describing methodology for creating open-source database of asset-level information on the steel and cement industries).

154. *Cervest Launches Cervest RatingsTM - the next Evolution of Its Ratings Methodology for Climate-Related Risk*, PRWEB, https://www.prweb.com/releases/2022/10/prweb18934482.htm [https://perma.cc/8ZZT-7FN8].

trusts ("REITs").[155] Using Geophy's database of 73,500 properties owned by 321 REITs, analysts enumerated which investment trust portfolios had the most at-risk assets in major cities. The assessment included limited commentary on vulnerability beyond exposure—noting that one New York City trust was significantly exposed to sea level rise but had recently invested in adaptation measures.[156] This information cannot be discovered from models alone and requires research into designs of physical assets, though the report did not go so far as to provide estimates of financial damage.

It is not clear, however, just how Moody's uses Four Twenty Seven's hazard information in its ratings agency business.[157] Understanding municipal bond risk requires assessment of vulnerability, like the likelihood of levee breaches, or ability of a community to recover following a disaster. Savannah Cox has documented that in addition to quantitative historic weather data and climate forecasts, Moody's analysts collect "qualitative intel" from sources like town managers and local press when assessing a town's "resilience."[158]

Active investors have already begun to make large financial bets based on climate projections, with some private equity firms branding themselves as "climate adaptation" focused.[159] Long-term bets on future profits are being made by investors buying up farmland in Canada,[160] or land in Asheville, NC, where they expect flooded-out Floridians to relocate.[161] These investors consult with climate scientists and "churn through" geographically linked data.[162] Bets on climate-induced resource scarcity are also being made. Harvard University's endowment has been criticized for buying up California vineyards and their rights to the water beneath them.[163] Wellington Asset Management—one of the top 20 U.S. asset managers with $1.2 trillion under

155. Kendall Starkman, *Report: Climate Risk, Real Estate, and the Bottom Line*, PREVENTIONWEB (Oct. 11, 2018), https://www.preventionweb.net/news/report-climate-risk-real-estate-and-bottom-line [https://perma.cc/2T9M-L5VW].

156. *Id*.

157. Cox, *supra* note 28.

158. *Id.*

159. Christopher Flavelle, *Climate Change Will Get Worse. These Investors Are Betting on It*, BLOOMBERG (Oct. 8, 2018), https://www.bloomberg.com/news/articles/2018-10-08/climate-change-will-get-worse-these-investors-are-betting-on-it.

160. Slate, *Cashing In on Climate Change*, SLATE MAGAZINE (Sep. 19, 2019), https://slate.com/business/2019/09/climate-change-crisis-companies-rich-lucky-farming-firefighting.html [https://perma.cc/7AJE-UEE9].

161. Flavelle, *supra* note 159.

162. Slate, *supra* note 160.

163. Richard Valdmanis, *Harvard Buys Up Water Rights in Drought-Hit Wine Country*, REUTERS (Jan. 22, 2015), https://www.reuters.com/article/us-harvard-water-idUSKBN0KV29G20150122?msclkid=e9966715ce5d11ecb9db3879046b6c94 [https://perma.cc/FMZ3-ZHCG].

management—partnered with Woodwell Climate Research Center to produce "an investor friendly climate exposure risk application tool," enabling investors to forecast physical risks to specific assets, in some cases down to the level of specific corporate equipment.[164] BlackRock hired its first in-house climate scientist in 2021.[165]

Some of the largest "real economy" (that is, non-financial) companies, particularly those with physical operations or supply chains with a widely dispersed and global reach, have developed sophisticated in-house physical climate analysis. Amazon is developing "a robust tool for assessing and managing weather and climate-related risks for [its] assets, people, and operations."[166] The company states that its "ultimate goal is to enable customers and suppliers to use the tools we are developing in-house to improve climate resilience."[167] Those without in-house expertise hire climate services consultants. Jupiter Intelligence advertises that it provides analytics to "at least one of the world's five largest firms in asset management, banking, insurance, oil and gas, mining, power, and construction."[168]

First Street Foundation, the group that rolled out nationwide "Fire Factor" scores before the Oregon state officials had finished their maps, claims to have built "the first comprehensive, publicly available flood risk model in the United States."[169] First Street's website hosts searchable flood, fire, and heat risk information for 142 million private and public properties. Every property is accompanied by a Factor®, a score ranging from one to ten, reflecting a property's risk over the course of a thirty-year mortgage.[170] First Street has partnered with popular real-estate search sites Redfin, Realtor.com, and

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164. *Wellington Management and Woods Hole Research Center Announce Strategic Climate Science Initiative*, BUS. WIRE (Sept. 24, 2018), https://www.businesswire.com/news/home/20180924005587/en/Wellington-Management-Woods-Hole-Research-Center-Announce [https://perma.cc/3BWD-M5YE]. In a promotional video, Wellington pitched: "We believe that marrying climate science and investment science gives us an edge because it can help us understand the financial risks of climate change before capital markets adjust and re-price for those risks."

165. *Is Your Fund Serious About Climate? Show Me Your Scientists.*, IMPACTALPHA (Aug. 25, 2021), https://impactalpha.com/is-your-fund-serious-about-climate-show-me-your-scientists/ [https://perma.cc/P2WK-NN5L].

166. AMAZON, ALL IN: STAYING THE COURSE ON OUR COMMITMENT TO SUSTAINABILITY 107 (2020), https://sustainability.aboutamazon.com/2019-sustainability-report.pdf [https://perma.cc/C3KW-PAX5].

167. *Id.*

168. *Jupiter's Solutions Span Industries, Use Cases, and Global Perils*, JUPITER, https://jupiterintel.com/solutions/ [https://perma.cc/35SQ-P7H7].

169. *Mission - First Street Foundation*, FIRSTSTREET, https://firststreet.org/mission/ [https://perma.cc/R6EB-89SV].

170. *Defining America's Past, Present, and Future Flood Risk*, FIRST ST. FOUND., https://firststreet.org/risk-factor/flood-factor/ [https://perma.cc/H4TB-AB4F].

Estately, to provide a property's Factor® score directly on its sale listing.[171] In some cases, First Street even provides dollar estimates of expected damages.[172] While First Street itself is a 501(c)(3) non-profit, a growing number of private companies have begun to license First Street's data for use in their own products and services. These include reinsurer Renaissance Re, DBRS Morningstar (a credit rater of mortgage-backed securities), and global engineering and consulting firm Arup.[173]

The preceding section is meant to be illustrative, not comprehensive. Some climate service providers sell or rely on physical risk information generated using simpler methodologies than those that Moody's employs. ESG ratings company Truvalue Labs, for example, does not purport to use climate modeling at all. Instead, the company uses "text-based analysis" of news reporting about public corporations to aggregate information about firm-level exposure to climate risk.[174] This approach is largely outside the scope of this article which limits its focus to the value-chain described above.

II. EMERGING CONCERNS

Following destructive flooding of the Vosso River in 2014, the Norwegian municipality of Voss contemplated steps for mitigating future flood events.[175] Several hydroelectric companies proposed diverting river water through a new mountain tunnel, thereby both reducing flood risk and generating electric power. As part of their bid, two companies hired a consultant to construct a 3D model of an extreme future flood event under projected climate change

171. *First Street Foundation's Partnerships and Impact Expand Greatly throughout 2022*, FIRSTSTREET, https://firststreet.org/press/press-release-2022-first-street-foundation-partnerships-2022/ [https://perma.cc/GZX6-R46N].

172. *Understanding First Street Foundation's Financial Impact of Flood Risk Report*, AM. FLOOD COAL.: AFC BLOG (Feb. 22, 2021), https://floodcoalition.org/2021/02/understanding-first-street-foundations-report-on-the-financial-impact-of-flood-risk-key-findings-and-questions/ [https://perma.cc/KC2Y-PBSF].

173. *First Street Foundation and Arup Announce Strategic Partnership To Help Organizations Tackle Climate Risk Across the US*, FIRST ST. FOUND. (July 28, 2021), https://firststreet.org/press/press-release-2021-arup-partnership/ [https://perma.cc/6EDE-EL83]; *DBRS Morningstar To Leverage First Street Foundation Data in Analysis of Credit Risk*, FIRST ST. FOUND. (Jan. 15, 2022), https://firststreet.org/research-lab/published-research/use-case-morningstar/ [https://perma.cc/LA7W-PEFU]; Katie Baker, *RenRe Partners with First Street Foundation To Tackle Flood Risk*, REINS. NEWS (Aug. 16, 2021), http://www.reinsurancene.ws/renre-partners-with-first-street-foundation-to-tackle-flood-risk/ [https://perma.cc/EJF7-WJ5P].

174. Hain et al., *supra* note 22.

175. Scott Bremer et al., *Toward a Multi-Faceted Conception of Co-Production of Climate Services*, 13 CLIMATE SERVS. 42, 44 (2019).

conditions.[176] In the midst of a contentious debate over protecting the river's ecology, the animation was played at a town meeting, where it depicted an unprecedented flood through the center of Voss "with massive damage to houses and infrastructure."[177] The model, as pointed out by Scott Bremer and his coauthors, demonstrated potential flooding under a high-emissions scenario, in which countries fail to meet reduction targets.[178] According to Bremer, some residents and local non-profits considered the video to be a "shock tactic" that "hid[] the cascading uncertainties inherent to the scenario on which the animation was built."[179]

In the growing "climate intelligence arms race" companies increasingly claim to use better science, better methods and models, and more comprehensive and granular data than their competitors.[180] As questions about downscaling methods and land use datasets leave research labs and enter PR pitches, the law is playing catchup. A growing number of experts caution that the financial sector is using outputs of GCMs without regard for their limitations. Beyond concerns over climate-specific scientific methodologies, a range of existing critiques from data, transparency, and accountability scholars apply to the climate services industry. Data providers and modelers hold substantial power through their control over what information gets considered, and how. This is especially true as the supply

176. *Id.*

177. *Id.*

178. *Id.* at 44. One key input to modeling future climate damages is how much the world will continue to emit in coming decades; different possible futures are modelled as "Representative Concentration Pathways" ("RCPs"). The Norwegian climate consultant had constructed its model based on RCP 8.5—the worst one—an emissions pathway some experts argue we are increasingly unlikely to follow as green energy accelerates. *See, e.g.*, Climate Nexus, *RCP 8.5: Business-as-Usual or a Worst-Case Scenario?*, CLIMATE NEXUS (Sep. 22, 2019), https://climatenexus.org/climate-change-news/rcp-8-5-business-as-usual-or-a-worst-case-scenario/ [https://perma.cc/ZJ4M-4W6S]; Zeke Hausfather, *Explainer: The High-Emissions 'RCP8.5' Global Warming Scenario*, CARBON BRIEF (Aug. 21, 2019) https://www.carbonbrief.org/explainer-the-high-emissions-rcp8-5-global-warming-scenario/ [https://perma.cc/JA3K-6L8F]; *cf.* Christopher R. Schwalm et al., *RCP8.5 Tracks Cumulative CO2 Emissions*, 117 PROC. NAT'L ACAD. OF SCIS. 19656, 19656 (2020) (arguing that RCP 8.5 has continued utility despite emissions forecasts that make it an increasingly unlikely future climate outcome).

179. Bremer et al., *supra* note 175, at 44. It should be noted that RCP 8.5 is very widely used throughout the public and private sector to represent either a "business as usual" or "worst case" scenario. *See* Climate Nexus, *supra* note 178. Recently, scientific debate about emissions trajectories and the likelihood of the RCP 8.5 path have become a part of the political rhetoric of the Republican right. Regulators and companies have both been accused of deceptively over-inflating climate damages through their reliance on the "worst case" unlikely scenario. But while RCP 8.5 is in fact unlikely, it is often used as an attempted of upper-bound test or range estimator to compensate for how poorly economic models are able to translate RCPs into impacts.

180. Keenan, *supra* note 19.

chain expands to include new "climate fintechs" that use big data tools enabled by artificial intelligence, remote sensing, cloud storage and computing.

A. Transparency

Various legal and structural barriers prevent third parties from both scrutinizing and utilizing climate services products. The complex climate risk models described above are built upon many different types of input datasets. Most raw weather data and GCM outputs are freely downloadable, but "cutting-edge" data useful for mapping hazards, like satellite-generated vegetation maps, may not be.[181] Exposure data like municipal infrastructure and corporate supply chains are even more likely to require a license. On top of this, many climate service providers employ proprietary models and methods that stay hidden within a black box and cannot be subject to consumer scrutiny or peer review.[182] Further, firms are not always transparent about the scientific limitations of how their data outputs can be used in the context of financial risk, even when charging a significant sum for their use.

The price tag for physical risk projections of flood, fires, and extreme heat at a specific location can reach into the millions.[183] Analysis that incorporates geographic granularity and uncertainty requires the use of downscaled GCM outputs and training on methodological approaches for addressing uncertainty and variability. While downscaled outputs of CMIP6 are publicly available, they require large amounts of computing power and expert guidance to work with.[184] Small municipalities and utilities are relatively in the dark about climate forecasts as compared to large cities or institutional investors paying to partner with the world's climate scientists. Alice Hill, for example, quotes the mayor of a small Alabama town on the Gulf of Mexico: "I don't have a big planning staff or any resources. So how can I even know the size of the threats we are facing, and what can I do to protect the people of my town?"[185] Local governments typically do not have computers

181. David Patterson et al., *Geospatial ESG: The Emerging Application of Geospatial Data for Gaining 'Environmental' Insights on the Asset, Corporate, and Sovereign Level* 5–6, 35 (2022).

182. *Id.*; Fiedler et al., *supra* note 25, at 88.

183. Hill, *supra* note 29.

184. Oriana Chegwidden et al., *Open Data and Tools for Multiple Methods of Global Climate Downscaling*, CARBON PLAN (2022). For example, AT&T's climate resilience study covering just four U.S. states would have taken a "standard computer" more than a decade to produce, but was completed by Argonne National Lab's supercomputers in months. https://about.att.com/content/dam/csr/PDFs/RoadToClimateResiliency.pdf

185. Hill, *supra* note 29.

powerful enough to work with multiple versions of downscaled data, even just regional sections. As the World Wildlife Fund notes, nonprofits can often only undertake this type of analysis through "donated resources from the tech sector, such as Google, Microsoft, or others."[186] The costs of obtaining the data as well as computational power to process it "means this is unviable for almost all academic and NGO applications."[187] Recently there been a growing effort to provide open-source downscaled data that can be accessed and analyzed in the cloud, but expertise and exposure data remain a barrier.[188]

Access to downscaled climate data and other information about hazard is only one small part of assessing community vulnerability and resilience. An effective assessment of climate risk often requires understanding a municipality's ability to recover from a disaster—which can be challenging given the costs of non-governmental data. A FEMA and DHS sponsored report on understanding community resilience pointed out that data on number of hospital beds per county, a key indicator for determining healthcare capacity, had to be purchased from the American Hospital Association.[189] Other indicators of disaster response, like hotel rooms by county, could only be "obtained from hospitality industry business intelligence companies who charge subscription fees for data access and analysis."[190]

Without transparency behind both data and methods, an end-user cannot properly evaluate the right application of climate risk tools. All risk assessment frameworks must make methodological choices—some pursue wider geographic coverage at the expense of more detailed location-specific modeling, for example. And with climate change projections, uncertainty is inescapable; how uncertainty is best resolved is dependent on the use-case.[191] But many climate risk scores and maps come with little accompanying context about their provenance, approach to dealing with uncertainty, or

186. *Id.*

187. Patterson et al., *supra* note 182, at 20.

188. *See, e.g.*, Sadie Frank & Oriana Chegwidden, *Why Climate Data Matters to Climate-Related Financial Risk Assessments*, CARBON PLAN (Aug. 1, 2022), https://carbonplan.org/research/data-financial-risk [https://perma.cc/6TPR-EZNU].

189. Lesley Edgemon, *Community Resilience Indicator Analysis: County-Level Analysis of Commonly Used Indicators From Peer-Reviewed Research* 97 (2020). (The research team chose not to purchase any datasets to ensure that counties could find the data for their county at no cost.)

190. *Id.*

191. *See, e.g.*, Julie A. Vano et al., *DOs and DON'Ts for Using Climate Change Information for Water Resource Planning and Management: Guidelines for Study Design*, 12 CLIMATE SERVS. 1 (2018).

guidance for how data should be used and not used.[192] The nonprofit Flood Coalition, for example, cautions that while First Street Foundation's nationwide data is useful for "risk awareness," it is not a substitute for detailed property-level stormwater modeling, and should not be used in regulatory decision making.[193] This same context and clarification is lacking on First Street's own site, which advertises recent data sales to both private insurance companies and Fannie Mae.[194] The physical risk scores produced by leading ESG firms have been found to have little correlation with one another.[195] Investors trying to picking between ESG scores have little to go on without accompanying methodological information.

B. Regulatory Licenses & Models Driving Markets

The underlying ideology of the government provision of weather forecasting services has long been to think of both data and forecasts as a public good.[196] The World Meteorological Organization ("WMO") maintains a global commons of weather observations and satellite data, and it has been longstanding WMO policy that weather data must be freely shared.[197] In

192. Oriana Chegwidden & Sadie Frank, *What Metadata Are Necessary for Interpreting a Climate Risk Assessment?,* CARBONPLAN (Jan. 30, 2023) https://carbonplan.org [https://perma.cc/XZ9A-CZFX]. *See also*, *Our Maps*, PROBABLE FUTURES, https://probablefutures.org/science/our-maps/ [https://perma.cc/GCF7-WPMM] (providing "guidance on how the data and the maps on this platform should (and should not) be used.")

193. *AFC's Perspective on First Street Foundation's Flood Factor Launch,* AMERICAN FLOOD COALITION (June 2020), https://floodcoalition.org/2020/06/afcs-perspective-on-first-street-foundations-flood-factor-launch/ [https://perma.cc/XU7G-A7QA].

194. *First Street Foundation's Partnerships and Impact Expand Greatly throughout 2022*, *supra* note 171.

195. Hain et al., *supra* note 22. Critiques of ESG scores in general have been growing, including for lack of consistency across providers, but the discrepancy is sometimes explained by disagreements about what constitutes "ESG." While one might expect more agreement when it comes to physical risk assessment, a recent study finds mostly divergence in scores of S&P500 companies.

196. Paul Edwards, *Predicting the Weather: An Information Commons for Europe and the World*, *in* COSMOPOLITAN COMMONS 155, 166 (Nil Disco & Eda Kranakis eds., 2013) ("In the interwar period, then, the prevailing moral economy of weather forecasting held that both data and forecasts should be generated by government agencies as a public service and treated as public goods—except in wartime, when governments halted the trans-border flow of weather data and military services treated weather forecasts as secret assets."); *see also* ANDREW BLUM, THE WEATHER MACHINE: HOW WE SEE INTO THE FUTURE (2019).

197. World Meteorological Organization [WMO], *WMO Policy and Practice for the Exchange of Meteorological and Related Data and Products Including Guidelines on Relationships in Commercial Meteorological Activities* (June 2001), https://www.weather.gov/tg/addprod1 [https://perma.cc/RQX8-K4S3] ("Members should reaffirm their commitment to the free and unrestricted international exchange of basic meteorological data and products, as defined in WMO Programmes . . . .").

1995, a group of European meteorological services successfully persuaded the WMO to change the rules, allowing the sale of products and "additional" data beyond those deemed "essential," which must remain free.[198] An ex-head of the WMO called the change the end of "the golden age of international cooperation in meteorology."[199] Bremer et al., writing from the UK, argue that "[c]limate services are continuing a long trend toward the privatization of previously public weather services."[200] Weather services and climate services are intricately connected, both relying on vast amounts of publicly collected data and complex atmospheric models.[201]

While Europe and the UK moved to privatize part of their state meteorological services in the 1980s, Reagan failed in his attempt to privatize the National Weather Service.[202] Congress then passed a bill prohibiting the transfer of certain weather operations to the private sector.[203] Starting in the mid-2000s, the push for privatization began to gain traction again.[204] In 2016, Congress implemented the NOAA Commercial Weather Data Program, encouraging the agency to rely on the private sector, including for satellite capabilities.[205] Gemma Cirac-Claveras documents the "data wars" around

198. *See id.*; *see also* Edwards, *Predicting the Future supra* note 196 at 179–80.

199. John W. Zillman, *Origin, Impact and Aftermath of WMO Resolution 40*, 68 WORLD METEOROLOGICAL ORG. BULL. (2019), https://public.wmo.int/en/resources/bulletin/origin-impact-and-aftermath-of-wmo-resolution-40 [https://perma.cc/WGB4-CEGC].

200. *See* Bremer et al., *supra* note 175 at 48; *see also* Andrew Freedman, *Weather is Turning into Big Business. And that Could Be Trouble for the Public.*, WASHINGTON POST (Nov. 25, 2019), https://www.washingtonpost.com/business/2019/11/25/weather-is-big-business-its-veering-toward-collision-with-federal-government/ [https://perma.cc/MAF6-PPFL].

201. PAUL N. EDWARDS, A VAST MACHINE: COMPUTER MODELS, CLIMATE DATA, AND THE POLITICS OF GLOBAL WARMING (MIT Press 2010).

202. Philip J. Hilts, *Reagan Took Solo Action on Weather Satellite Sale*, WASH. POST (Mar. 26, 1983), https://www.washingtonpost.com/archive/politics/1983/03/26/reagan-took-solo-action-on-weather-satellite-sale/0f572933-f5f1-45e5-8f6d-cc1c5ad46c9a/ [https://perma.cc/4LSG-GST2]; *see also What's the Weather? Don't Ask the Service*, N.Y. TIMES, Sept. 10, 1990, at B10 ("Seeking to distance this latest effort from an aborted attempt in 1983 by the Reagan Administration to sell the nation's weather satellites, Dr. Friday said he resists calling the new plan the privatization of weather information.").

203. Gemma Cirac-Claveras, *The Weather Privateers: Meteorology and Commercial Satellite Data*, 53 INFORMATION & CULTURE 271, 272 (2018) ("It was seen to be in the national interest and general public good to ensure that data were collected, archived, and disseminated freely and free of charge to users worldwide.").

204. *See id.* at 276–77. (describing how beginning in the mid-2000s, there was a political fight over whether to turn over part of NOAA's public satellite operations to private contractors; this resistance to privatization began to shift, as evidenced by Obama's Space Policy of 2010, which sought to encourage commercialization of space activities)

205. *See id*. at 290 ("On April 18, 2017, President Trump signed the Weather Research and Forecasting Innovation Act, directing NOAA to enter into agreements for commercial satellite weather data purchases, including GNSS-RO data, and to consider them as an alternative to future NOAA space systems.").

this time, with the private sector pointing to NOAA's failures to keep up with Europe's weather forecasting capabilities and calling the agency "immersed in bureaucratic inertia" and "immobilism."[206] In response, academic scientists and the American Meteorological Society warned "that the private sector had attracted publicity with untenable promises and disinformation, and was deliberately misleading the public and Congress."[207]

NOAA currently makes decisions about what private weather data to buy, from which companies.[208] Not only the price tag, but concerns over data reliability, and whether the provider will stay in business, are all weighed when deciding whether to replace government-generated data with private sources.[209] But this data—which may be useful for predicting potential disasters—may also come with licensing strings and limitations on how its outputs can be shared with the public.[210] Andrew Blum worries that this trend has the potential to "bifurcate the global system [and] erode the foundations of global data exchange of [public] global weather data that have really built the system we have today.[211]

Government regulatory bodies relying on third-party data and models built by private contractors come with a host of documented accountability concerns. The Freedom of Information Act and other public records laws

206. *Id.* at 287.

207. *Id.* at 286–87.

208. In 2006, and again in 2016, Republican congressmen introduced bills prohibiting the National Weather Service from competing with the private sector. Their intent was to limit NOAA's mission to upstream data collection and modeling, leaving all downstream weather services to private industry. *See* Angela Fritz, *Congress Is Considering Privatizing Key Roles of the Weather Service. That's a Mistake.*, WASH. POST (June 9, 2016), https://www.washingtonpost.com/news/capital-weather-gang/wp/2016/06/09/congress-is-considering-privatizing-key-roles-of-the-weather-service-thats-a-mistake/ [https://perma.cc/9D9V-EXGU] ("NOAA should focus on providing the foundational datasets that others utilize to produce life-saving forecasts, rather than duplicating efforts and technologies that are employed or could be employed by the private sector"). Privatization forces finally succeeded when Trump signed the PROSWIFT Act into law in 2020, directing NOAA to begin purchasing private weather data. Jeff Foust, *House Committee Presses NOAA on Commercial Weather Data and Space Traffic Management*, SPACE NEWS (Sept. 24, 2021), https://spacenews.com/house-committee-presses-noaa-on-commercial-weather-data-and-space-traffic-management/ [https://perma.cc/Z6RU-Q3MR] ("The Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act, enacted in October 2020, directed NOAA to establish a pilot program for purchasing space weather data within 12 months of its enactment. However, [Rep. Frank Lucas] noted NOAA issued a request for information before the bill's passage but found no companies that meet its mission needs.").

209. Freedman, *White House Launches "Climate Services" Push*, *supra* note 200.

210. *Id.*; *see also* BLUM, *supra* note 196.

211. BLUM, *supra* note 196.

cover in-house government built models, but do not reach private vendors.[212] And Administrative Procedure Act requirements that the public be given opportunity to comment on the bases for rulemaking may be thwarted by their use as well.[213] In October 2022, it was announced that the Federal National Mortgage Association, commonly known as Fannie Mae, had acquired the use of First Street Foundation's parcel-level "climate adjusted risk data" to use in its analysis of risks to the U.S. mortgage market.[214] First Street has been successful at getting itself described in the press as "democratizing" climate information, despite its "Pro" tiered paywall structure and numerous private sector partnerships.[215]

Across the Atlantic, the European Central Bank climate stress tests drew on Moody's flood risk and asset location data.[216] If banking regulators in the United States follow a similar approach, then the regulators, the financial actors that have purchased Moody's data, and one of the leading ratings agencies would all be relying on the same model outputs.[217] Financial actors

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212. Hannah Bloch-Wehba, *Transparency's AI Problem*, KNIGHT FIRST AMENDMENT INSTITUTE (2021).

213. Kimberly N Brown, *"We the People," Constitutional Accountability, and Outsourcing Government*, 88 INDIANA L. J. 1347 (2013).

214. *First Street Foundation Partners with Fannie Mae to Deliver Climate Risk Insights*, FIRSTSTREET, https://firststreet.org/press/press-release-2022-fannie-mae/ [https://perma.cc/QL52-W7JH].

215. Compare *Millions of U.S. Homes at Risk of Climate-Related Disasters, but Few Americans Know It*, USA TODAY (Aug. 11, 2021), https://www.usatoday.com/story/news/investigations/2021/08/11/climate-change-threatens-millions-american-homes-flood-fires/5512876001/ [https://perma.cc/D8Y5-9T5X]; Alex Kuffner, *Rising Threat: New Study Finds Thousands More Properties at Risk of Flooding in 100-Year Storm*, THE PROVIDENCE JOURNAL, https://www.providencejournal.com/story/news/environment/2020/06/28/rising-threat-new-study-finds-thousands-more-properties-at-risk-of-flooding-in-100-year-storm/42401071/ [https://perma.cc/SJ9K-TWUK] *with "*Pricing," RiskFactor.com, https://riskfactor.com/pricing [https://perma.cc/6CPK-ERQA] (advertising $200,000/year pricing for "Risk Factor Pro Portfolio" service); *First Street Foundation's Partnerships and Impact Expand Greatly throughout 2022*, FIRSTSTREET, https://firststreet.org/press/press-release-2022-first-street-foundation-partnerships-2022/ [https://perma.cc/GZX6-R46N].

216. Spyros Alogoskoufis et al., *Occasional Paper Series: ECB Economy-Wide Climate Stress Test*, EUROPEAN CENTRAL BANK (Sept. 2021) at 77, https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op281~05a7735b1c.en.pdf [https://perma.cc/YN4H-M24S]. *Macro-Financial Scenarios for the 2022 Climate Risk Stress Test*, EUROPEAN CENTRAL BANK 4 (Jan. 2022), https://www.bankingsupervision.europa.eu/ecb/pub/pdf/ssm.macrofinancialscenariosclimaterisk stresstest2022~bcac934986.en.pdf [https://perma.cc/97U6-Z2UB].

217. *See, e.g.,* Savannah Cox, John Hogan Morris, & Zac Taylor, *Risk-Rating and Networked Authority: A Climate Leviathan in Formation?* LPE PROJECT (June 12, 2023), https://lpeproject.org/blog/risk-rating-and-networked-authority-a-climate-leviathan-in-formation/.

may think they are using different sources of risk assessment information from different providers, when in fact both assessments rely on the same upstream datasets. These opaque redundancies may mask uncertainty and in fact amplify risk.

Regulatory overreliance on ratings agencies was a topic of scrutiny following the Global Financial Crisis.[218] In the aftermath of 2008, it was agreed that the ratings agencies played a significant role by mispresenting the risk of complex packages of mortgage-backed securities.[219] Regulators deferred oversight of the subprime market to the judgment of ratings agencies, and then failed to monitor the agencies.[220] Some argue, including former employees, that Moody's going public in 2000 meant the company was newly exposed to shareholder pressure.[221] As shareholders amended executive pay to incentivize returns, this short-termist shift (combined with the issuer-pays model of the ratings business) led to Moody's devoting fewer resources to training and modeling.[222] The Dodd-Frank Wall Street Reform and Consumer Protection Act required federal agencies to remove all direct references to ratings from their regulations and guidance.[223] But as Jeremy Kress describes, this elimination of "regulation subsidies" to agencies was not accompanied by any rigorous plan for what would replace private risk ratings.[224] Currently, financial regulators are contemplating capital requirements and stress tests that incorporate climate risk information. With a potential for regulators to hire private contractors and consultants as climate services providers, there has been little discussion of how this reliance has

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218. *See, e.g.*, Panayotis Gavras, *Ratings Game*, 49 FIN. & DEV. 34 (2012) (arguing that "private credit rating agencies have been thrust into providing a public function because regulators have not come up with an alternative").

219. ROBERT W. KOLB, LESSONS FROM THE FINANCIAL CRISIS: CAUSES, CONSEQUENCES, AND OUR ECONOMIC FUTURE (Wiley 1st ed. 2010) ("[T]he credit ratings provided by the agencies were accepted without adequate knowledge of the risks of the underlying mortgage portfolios.").

220. Panayotis Gavras, *supra* note 218; Zachary Mollengarden, *Credit Ratings, Congress, and Mandatory Self Reliance*, 36 YALE L. & POL. REV. 473 (2018) (pointing to a "'mechanistic overreliance' on the opinions of a small number of eminently fallible (and… fundamentally conflicted) firms").

221. *See generally* Steven H Kasoff & Matthew A Lieber, *Lessons Learned: Eric Kolchinsky*, 4 J. FIN. CRISES 429 (2022).

222. *Id. See also* Ingo Fender & John Kiff, *CDO Rating Methodology: Some Thoughts on Model Risk and Its Implications* 2 (Bank for Int'l Settlements, Working Paper No. 163, 2004) (warning that "methodological differences [in rating risk] may generate incentives for issuers to strategically select rating agencies to . . . engage in 'ratings shopping'").

223. Dodd-Frank Wall Street Reform and Consumer Protection Act, Pub. L. No. 111-203, 124 Stat. 1376 (2010), § 939A(a)(2).

224. Jeremy Kress, *Banking's Climate Conundrum* 59 AM. BUS. L. J. 679, 698 (2022) ("To comply with section 939A, the U.S. banking agencies ultimately replaced references to credit ratings with relatively crude risk-weighting methodologies.").

the potential to shape investments in the economy in similar ways as credit ratings prior to 2008.

FutureProof is a venture-capital-funded startup that offers physical risk "projections cover[ing] all six populated continents under multiple climate scenarios from the present to 2100."[225] After the Biden administration announced its intent to enhance regulatory requirements for corporate disclosures of climate-related risks, FutureProof offered its services for free to government regulators.[226] This arrangement poses an interesting set of questions and problems. If regulators are to assess whether corporate physical risk disclosures are "correct," will they rely on FutureProof's projections? Does that then increase the necessity of companies using FutureProof's modeling data, rather than say a competitor's that forecasts a different level of risk? Who evaluates which version of the future is correct? Frank Partnoy has pointed to the "regulatory licenses" federal agencies grant to financial service providers when they rely upon them to play crucial gatekeeping roles, such as providing ratings.[227] These licenses become path dependent and self-replicating; they become institutionalized in a way that becomes much harder to de-embed from the regulatory apparatus later.

C. Who Owns the Future?[228]

It is well documented that extreme weather events have disproportionately impacted black and brown communities in the United

225. Rebecca Szkutak, *FutureProof Raises $3 Million Seed Round and Opens Its Climate Risk Platform to Regulators*, FORBES (June 29, 2021), https://www.forbes.com/sites/rebeccaszkutak/2021/06/29/futureproof-raises-3-million-seed-round-and-opens-its-climate-risk-platform-to-regulators/?sh=28b255017064; *Equilibrium and FutureProof Announce Climate Risk Asset Pricing Partnership*, PR NEWSWIRE (July 8, 2021, 11:00 AM), https://www.prnewswire.com/news-releases/equilibrium-and-futureproof-announce-climate-risk-asset-pricing-partnership-301327865.html [https://perma.cc/75DG-W9QV].

226. Szkutak, supra note 225; PR NEWSWIRE, *supra* note 225.

227. This practice continues as the Fed, despite the statutory directive of the Dodd-Frank Act, relied upon external credit ratings when determining bailout eligibility during the 2020 crisis. *See* Joe Pimbley & Bill Harrington, *Federal Reserve Trashes Dodd-Frank Restrictions on Credit Ratings*, CROATAN INST. (May 20, 2020), https://croataninstitute.org/2020/05/20/federal-reserve-trashes-dodd-frank-restrictions-on-credit-ratings/ [https://perma.cc/A3XA-TUDS].

228. *Cf.* JARON LANIER, WHO OWNS THE FUTURE? (2013).

States.[229] This trend is destined to accelerate as the climate changes.[230] In addition to receiving less investment in infrastructure and less post-disaster relief, communities of color are also likely to suffer from an information deficit: there is simply less information being generated and disseminated about climate risks facing communities of color than white communities.[231] That Federal Emergency Management Agency's ("FEMA") flood maps are badly outdated and fail to account sufficiently for present-day risk is widely acknowledged.[232] Less well known is that people of color are overrepresented in unmapped flood areas.[233] Both the National Weather Service and the private sector provide more accurate forecasts for areas with either higher population density or higher average income.[234]

In her book *Underwater*, Rebecca Elliott describes the multi-year conflict around FEMA's updated mapping of flood zones following Superstorm Sandy. FEMA only considers flood zone appeals if they bring forward "new information" that challenges the scientific or technical accuracy of the agency's determination.[235] New York City hired a private consultant to help argue FEMA had used incorrect elevation information and mislabeled hundreds of thousands of properties as high-risk. The consultant cost millions of dollars, a price other municipalities in the process of risk re-ratings cannot

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229. *Climate Change and Social Responsibility: Helping Corporate Boards and Investors Make Decisions for a Sustainable World: Hearing Before the Subcomm. on Inv. Prot., Entrepreneurship & Cap. Markets of the H. Comm. Fin. Servs.*, 117th Cong. 8 (2021) [hereinafter *Helping Corporate Boards and Investors*] (statement of Heather McTeer Toney, Climate Justice Liaison, Environmental Defense Fund and Senior Advisor, Moms Clear Air Force) ("How is it that in a system managed by federal oversight of agencies responsible for the disaster assessment and response, inequities continue to exist? I submit that it can directly tied [sic] to the missing piece of business/corporation climate risk disclosure.").

230. *The Link Between Historic Redlining and Current Climate Risks*, ENTERPRISE CMTY. PARTNERS, INC. (Aug. 5, 2021), https://www.enterprisecommunity.org/blog/link-between-historic-redlining-and-current-climate-risks [https://perma.cc/J8HX-WC6H].

231. A EUROPEAN RESEARCH AND INNOVATION ROADMAP FOR CLIMATE SERVICES, EUR. COMM'N 47 (2006).

232. *Are FEMA Flood Maps Accurate?*, KIN INSURANCE (Jan. 11, 2022), https://www.kin.com/blog/fema-flood-maps#:~:text=FEMA's%20maps%20are%20outdated%20and,required%20to%20have%20flood%20insurance [https://perma.cc/49DN-77WD].

233. Christopher Flavelle et al., *New Data Reveals Hidden Flood Risk Across America*, N.Y. TIMES (June 29, 2020), https://www.nytimes.com/interactive/2020/06/29/climate/hidden-flood-risk-maps.html.

234. Nejat Anbarci et al., *Population and Income Sensitivity of Private and Public Weather Forecasting*, 41 REG'L SCI. & URB. ECON. 124, 125 (2011); *see also* Marshall Shepherd, *Are Black And Rural Residents in The South More Vulnerable To Tornadoes Due To Radar Gaps?*, FORBES (Mar. 20, 2021), https://www.forbes.com/sites/marshallshepherd/2021/03/20/are-black-and-rural-residents-in-the-south-more-vulnerable-to-tornadoes-due-to-radar-gaps/.

235. Elliott, *supra* note 26 at 109 (citing GAO-11-17 FEMA Flood Maps).

afford. In coastal Florida, there are companies, such as Flood Risk Solutions, Inc., that help real estate developers fight FEMA risk designations.[236] FEMA grants a reported eighty-nine percent of the 30,000 flood map appeals it hears a year, including for properties with a record of flood loss.[237]

In *Rule by Data: The End of Markets?*, Katarina Pistor writes about Big Tech's ability to profit from an "asymmetry of predictive power at the expense of . . . consumers."[238] She focuses on the "predictive power of data to estimate consumer behavior" rather than the power to predict future weather hazards.[239] With climate services, certain big data concerns such as nonconsensual harvesting of personal information are typically not applicable.[240] However, much of the analogy still usefully holds. In particular, Pistor raises concerns over the monopolization of predictive information and Big Tech's selective granting of access. She argues this is potentially problematic given the non-excludable and non-rivalrous character of predictive data: any number of consumers could simultaneously use this knowledge product.[241] These qualities suggest to Pistor that predictive power should be considered a public good.[242]

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236. Bill Dedman, *Meet the Flood Insurance 'Robin Hood' Who Saves Condo Owners Millions*, NBC NEWS (Feb. 19, 2014), https://www.nbcnews.com/news/investigations/meet-flood-insurance-robin-hood-who-saves-condo-owners-millions-n26711 [https://perma.cc/R7YC-YFJH] ("Flood Risk Solutions, LLC, does not work for owners of single-family homes, only for commercial real estate companies.").

237. Miranda Leitsinger, *For Average Joes, Fighting FEMA Flood Maps Isn't Easy or Cheap*, NBC NEWS (Feb. 20, 2014), https://www.nbcnews.com/news/us-news/average-joes-fighting-fema-flood-maps-isnt-easy-or-cheap-n23871 [https://perma.cc/GP8Q-JH2R]; Bill Dedman, *Why Taxpayers Will Bail Out the Rich When the Next Storm Hits US*, NBC NEWS (Feb. 18, 2014), https://www.nbcnews.com/news/investigations/why-taxpayers-will-bail-out-rich-when-next-storm-hits-n25901 [https://perma.cc/46G7-PYZP].

238. Katharina Pistor, *Rule by Data: The End of Markets?*, 83 LAW & CONTEMP. PROBS. 101, 102 (2021).

239. *Id.* at 103.

240. *But cf.* Angelina Fisher & Thomas Streinz, *Confronting Data Inequality*, 60 COLUM. J. TRANSNAT'L L. 829, 862, 890 (2022) (discussing asymmetry of power in contracts between Monsanto's Climate Corporation and farmers who purchase their weather modeling tools). The data from farmers' own fields and equipment is sent back to Monsanto to develop cutting-edge analytics of nationwide crop production, giving the company advanced insight into gluts and shortages. *Id.*

241. *See* Pistor, *supra* note 238, at 119.

242. *See id.* (citing MANCUR OLSON, THE LOGIC OF COLLECTIVE ACTION: PUBLIC GOODS AND THE THEORY OF GROUPS (1971)); Elinor Ostrom, *How Types of Goods and Property Rights Jointly Affect Collective Action*, 15 J. THEORETICAL POL. 239 (2003); *see also* Bremer et al., *supra* note 175 at 48 ("We see potential tensions between climate services as public or private goods, and how they are used in public and private arenas.").

The NGFS appears to agree with Pistor, calling its own directory of climate risk data a "public good."[243] But around half the data contained in the directory is either proprietary or requires a subscription.[244] Many new climate analytics providers claim to be "democratizing" climate data, including those selling fee services pitched to investors.[245] But even providers pitching "free" tools to the public rarely develop them through an institutional process one would call "democratic." The issue of data inequality is "not only [about] having or not having data, but also [about] having or not having the power to decide what kind of data is being generated and in what form or format, how and where it is amassed and used, by whom, for what purpose, and for whose benefit."[246] Thomas Streinz and Angelina Fisher call this the "power to datafy," and, in a context that extends beyond climate services to all big data, point out that "[m]any of the relevant decisions *about what becomes data* (i.e. what is being datafied) are made by commercial actors who exercise varying degrees of control over data infrastructures through which data is ultimately generated and processed."[247]

While there has been a recent push for climate risk-related "open data" pools managed by regulators, or industry associations, there has been little reflection on who will be able to use this data and for what purposes.[248] Working with downscaled, geospatial, climate information requires a huge amount of computing power and data support from humans.[249] Junior climate scientists in academia have complained that they are frequently relegated to data processing tasks in their graduate and postdoctoral research.[250] This means they are not able to spend time on other under-addressed applications,

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243. NETWORK FOR GREENING THE FINANCIAL SYSTEM, FINAL REPORT ON BRIDGING DATA GAPS 8 (2022).

244. *Id.* at 29.

245. *About Us and Our Mission*, CERVEST, https://cervest.earth/about [https://perma.cc/2GUM-BNSV]; *see also How Google Will Help End Deforestation in Our Supply Chain*, UNILEVER, https://www.unilever.com/news/news-search/2020/how-google-will-help-end-deforestation-in-our-supply-chain [https://perma.cc/L3U6-M2WB]; Joe Dana, *Find out Your Home's Risk Level for Wildfires and Flooding*, 12 NEWS (May 22, 2022), https://www.12news.com/article/tech/science/environment/find-out-the-risk-level-of-wildfire-and-flooding-to-your-home/75-8c2fe989-202f-4c38-a3d7-ee755fdf579e [https://perma.cc/3PJ7-PYX4] (noting First Street Foundation's self-stated mission to "democratize data").

246. Fisher & Streinz, *supra* note 240, at 831.

247. *Id.* at 845; *see also* CATHERINE D'IGNAZIO & LAUREN F. KLEIN, DATA FEMINISM (2020) ("Today, data science is a form of power.").

248. *Cf.* D'IGNAZIO & KLEIN, *supra* note 247 (arguing that the practice of collecting and selling large datasets without accompanying documentation or meta-data makes it impossible to evaluate the data "in relation to the 'knowledge infrastructure' from which they originate . . . i.e., the context that makes the data possible")

249. Vano et al., *supra* note 191.

250. Jain et al., *supra* note 84, at 1.

like expanding adaption information for the Global South.[251] Further, the adoption of more accurate and elaborate risk assessments using the "bottom-up" approach means there is a need for data beyond climate models: elevation, floor plans, weather history, landcover, supply chains, and more. One risk analytics company providing models to insurers was featured in the Wall Street Journal as having a database that "can distinguish between 14 types of restaurants—from a pub to a white-tablecloth establishment."[252] A policy emphasis on ever-increasing "data lakes" does not address the bottleneck that occurs when there is a lack of resources for translating upstream data to usable downstream information.[253]

D. The Limits of Models

Beyond the difficulties of climate modeling, an asset's true climate-related risk stems not just from its own exposure, but whether the infrastructure and services the asset relies on will be resilient in the face of increasingly severe and potentially co-occurring extreme events. A business depends not just on its physical assets but also on supply chains, workers, and municipal infrastructure. Real estate investors and ratings agencies are already investigating things like sea level rise adaptation projects, hazard mitigation plans, and ability to recover financially following a disaster.[254] One large investment manager used Four Twenty Seven's sea-level rise data to determine that while a particular investment property of interest was not itself at risk, the greater municipality was likely to be inundated and "had limited mitigation measures in place."[255] This systemic understanding of the way climate change can pose a risk not just directly, but indirectly, is not captured in top-down models or simple hazard scores.

While these active real estate owners follow a bottom-up approach when assessing risk for potential properties, this approach becomes necessarily harder for many assets in many geographies. In this arena, large insurers and

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251. *Id.* at 3.

252. Richard Vanderford, *Insurers Harness Data To Help Clients Weather Storms, Floods*, WALL ST. J. (June 24, 2022), https://www.wsj.com/articles/insurers-harness-data-to-help-clients-weather-storms-floods-11656063001?mod=article_relatedinline [https://perma.cc/QH4A-77KT].

253. *Cf.* Annie Brett, *Information as Power: Democratizing Environmental Data*, 22 UTAH. L. REV. 127, 142 (2022) ("The result is data systems that are public in name only. . . . While many environmental agencies and regulations require stakeholder consultation and incorporation of traditional knowledge where possible, the data systems that these agencies use to make decisions systemically exclude many stakeholders.")

254. KATHARINE BURGESS & BILLY GRAYSON, CLIMATE RISK AND REAL ESTATE EMERGING PRACTICES FOR MARKET ASSESSMENT (2020).

255. *Id.*

reinsurers employing catastrophe models are the leaders in bottom-up risk assessments of financial exposure to extreme events. However, cat models at the scale of re-insurance take two to three years to build, requiring a team of ten to twenty PhD experts from a range of disciplines, including meteorology, hydrology, engineering, and computer science.[256]

And climate risk is not just hazard, or the probability of extreme precipitation calculated by scientists. It is also vulnerability, or how exposed or adapted you are to the hazard—which is a fundamentally interdisciplinary and systemic question. Facebook and Google built billion-dollar campuses on the edge of San Francisco Bay that now must be protected by a massive levy project, the success of which may be determined by whether the tech giants agree to pay more of the construction costs.[257] As some real estate investors have already discovered, there is an inseparable relationship between private financial risk and local capacity for adaptation. For example, in Chile, a decades-long conflict over privatized water rights has worried miners that they may lose their "social license to operate" if scarcity becomes too extreme, or political will shifts for reform.[258] Amid extreme drought in 2021, Chilean lawmakers passed a bill that had been proposed ten years before, prioritizing human consumption, and forcing companies to contemplate constructing expensive desalination plants, or indefinitely postpone projects.[259] Predicting not only the severity of the drought, but what the societal response to it might be is extremely challenging—Chile's water reform success was linked to a broader social tipping point occurring in the country.[260]

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256. GOLNARAGHI, *supra* note 131.

257. Lauren Sommer, *Who Will Pay To Protect Tech Giants from Rising Seas*, NPR (2021), https://apps.npr.org/sea-level-rise-silicon-valley/.

258. Mirja Schoderer & Marlen Ott, *Contested Water- and Miningscapes—Explaining the High Intensity of Water and Mining Conflicts in a Meta-Study*, 154 WORLD DEV. 1, 3, 7 (2022); Cecilia Jamasmie, *Chile Set To Make Mining Desalination Mandatory*, MINING.COM (Jan. 2, 2014), https://www.mining.com/chile-set-to-make-mining-desalination-mandatory-57150/; INNOVATION IN MINING: LATIN AMERICA 2017, DELOITTE (2017).

259. *Chile's Dictatorship-Era Water Code Is Getting a Makeover*, REUTERS (Aug. 4, 2021, 6:48 PM), https://www.reuters.com/world/americas/chiles-dictatorship-era-water-code-is-getting-makeover-2021-08-05/ [https://perma.cc/P5SR-MAZ9]; Fabian Cambero, *Chile's Parched Mines Race for an Increasingly Scarce Commodity: Water*, REUTERS (May 6, 2022, 3:27 AM), https://www.reuters.com/world/americas/chiles-parched-mines-race-an-increasingly-scarce-commodity-water-2022-05-06/ [https://perma.cc/B28Z-ASAA] (describing the political and logistical obstacles involved in creating desalination plants in Chile).

260. *Cf.* Siping Guo, *How Climate Change Affected Thirsty Chipmakers*, MORGAN STANLEY CAP. INT'L (Nov. 9, 2021), https://www.msci.com/www/blog-posts/how-climate-change-affected/02841370014 [https://perma.cc/EZ9B-NYW8] (noting that during Taiwan's severe 2021 drought, authorities imposed water-use restrictions on municipalities, residents, and agriculture—in part, to prioritize use in the semiconductor industry).

Not all physical climate risk assessments are useless—we need to adapt and build infrastructure high enough to withstand sea level rise. But even this risk assessment, made at the very bottom of the bottom-up approach, is a complicated task when undertaken with due respect to scientific uncertainty. How much should you spend on a seawall when there is "deep uncertainty" over how high the sea will rise?[261] This question about deep uncertainty already exists at the level of evaluating risk to one asset from one climate impact at one location. It necessarily compounds at the level of a corporation with many assets dependent on many supply chains facing many risks, and again at the level of a financial portfolio invested in many corporations.

III. SOLUTIONS?

In July 2022, the U.S. Department of the Treasury announced the creation of a "Climate Data and Analytics Hub" to serve as a convening resource between the Federal Reserve and Treasury, with plans to expand to the other financial regulatory agencies.[262] This Analytics Hub suggests that Treasury appreciates the data-intensive nature of climate risk assessment. However, it appears that agencies with scientific, environmental, or disaster risk expertise are not participants in the Hub. Such collaboration is crucial to ensure that regulators are using the data and analysis within their underlying scientific limits. The Federal Reserve's "Pilot Climate Scenario Analysis Exercise," released in January 2023, demonstrated exactly this failure of disciplinary tunnel-vision. The Fed asks banks to analyze the risk to a portion of their real estate portfolios from a large hurricane landfall on the East Coast.[263] Banks are instructed to model losses as if it were the year 2050 under two possible emissions futures—one high and one low.[264] The problem is that, as the reader knows by now, hurricanes are complex hazards—many different factors influence their level of devastation.[265] Science is still confused about the effect of climate change on hurricanes in general, let alone its effect on the distribution of hurricane intensity specifically in the New York region in the year 2050.[266]

Further, information on climate risk is needed by many, if not all, agencies, not just financial regulators. Like climate change, decisions by one

261. Doss-Gollin & Keller, *supra* note 110.

262. Press Release, U.S. Dep't of the Treasury, *supra* note 36.

263. PILOT CLIMATE SCENARIO ANALYSIS EXERCISE, PARTICIPANT INSTRUCTIONS, BD. OF GOVERNORS OF THE FED. RESERVE SYS. (2023).

264. *Id.*

265. Hereid, *supra* note 65.

266. R. Saravanan, *supra* note 63.

regulator can have a systemic effect on trends or crises impacting other regulators. Regulation of climate risk in the mortgage market, or the pricing of federal flood insurance, can lead to significant downstream effects on resilience, grant funding, demographics, and local economies. As the extreme impacts of climate change pick up pace, the systemic nature of our adaptive choices will increase.

We need a centralized provider of climate data in the form of a National Climate Service ("NCS") to both serve as a "public option"—an alternative to private providers—and to guide federal regulators, including financial regulators. To effectively meet its many needs, an NCS should follow a "hub and spokes" approach, with some resources focused on the convening agency, and others focused on a regional network of research, consultation, and communication centers.[267] Beyond processing and providing information, regulators should contemplate what existing law and policy tools can be used to increase the sharing of private information on climate hazards, as well as their oversight.

A. National Climate Service

In 2011, the National Oceanographic and Atmospheric Administration ("NOAA") proposed reorganizing its offices to establish a National Climate Service, citing a skyrocketing demand for adaptation information from farmers, urban planners, insurers, and beyond.[268] NOAA argued to Congress that it was merely seeking permission to reallocate its existing budget, as the authority to establish an NCS had been granted under the National Climate Program Act ("NCPA") of 1978.[269] The NCPA was not only America's first national climate legislation, but also its first law aimed at the production of climate services.[270] Its bipartisan cosponsors, including Sunbelt Republicans

267. *See, e.g.*, Robert E. Kopp, *Land-Grant Lessons for Anthropocene Universities*, CLIMATIC CHANGE, Mar. 2021.

268. Brian Vastag, *Congress Nixes National Climate Service*, WASH. POST (Nov. 20, 2011), https://www.washingtonpost.com/national/health-science/congress-nixes-national-climate-service/2011/11/18/gIQAxYvIgN_story.html [https://perma.cc/J49B-SS5X]. The idea for an NCS had been "floating around" NOAA since the late 1970s, and had gained official support from both the Bush and Obama administrations. Kwok, *supra* note 43; *see also U.S. Official Proposes National Climate Service*, NBC NEWS (May 14, 2008), https://www.nbcnews.com/id/wbna24613577 [https://perma.cc/Z8QE-EJ4R].

269. Lauren Morello, *Agency Proposes Climate Service To Spur Adaptation*, N.Y. TIMES (Feb. 9, 2010) https://archive.nytimes.com/www.nytimes.com/cwire/2010/02/09/09climatewire-agency-will-create-national-climate-service-63603.html.

270. Gabriel Henderson, *Governing the Hazards of Climate: The Development of the National Climate Program Act, 1977—1981*, 46 HISTORICAL STUD. NAT. SCIENCES 207, 213 (2016).

with agricultural interests, were concerned about regional climate change impacts on food production and water resources.[271] The statute's text calls for user-focused "applied research and advisory services," along with the provision of "reliable, useful and readily available information on a continuing basis."[272] While NOAA's six Regional Climate Centers owe their existence to the NCPA, the Act's scattered interagency design thwarted its goal of "active dissemination of climatological data, information, and assessments, including mechanisms for consultation with current and potential users."[273] Which was why in 2011, NOAA sought to establish a centralized NCS.

Congress denied the agency's request, with Republicans now worrying that "climate services could become little propaganda sources."[274] NOAA had argued that a NCS was necessary because climate information was spread across many agencies and potential users were "confused where to go for climate information."[275] The Government Accountability Office ("GAO") agreed in a later report, arguing that a national climate information system was necessary to coordinate data "fragmented across individual agencies."[276] This federal climate information system would serve, in part, to issue "authoritative federal data and federal quality assurance guidelines."[277]

Political interest in a centralized Climate Service has renewed. The House Climate Crisis Committee's 2020 Action Plan calls for the government to "develop and deploy actionable climate risk information."[278] To that end, the Plan calls for the establishment of two bodies. The first, a Climate Risk Information Service, would "develop and maintain a centralized portal for access to authoritative climate risk information geared toward public-and

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271. *Id.* at 219.

272. National Climate Program Act, Pub. L. No. 95-367, 92 Stat. 601 (1978) .

273. *Id.*; *see also* ADVANCING THE SCIENCE OF CLIMATE CHANGE, NAT'L RSCH. COUNCIL 493 (2010) (explaining that even though the NCPA "established the National Climate Program Office as an interagency program[,] . . . the Act's budget mechanism did not facilitate a coordinated and integrated program because each department and agency could and often did act independently in its budget submission").

274. *See* Vastag, *supra* note 268. One representative even launched an investigation into whether NOAA was operating "a shadow climate service operation." *Id.*

275. *Id.*

276. U.S. GOV'T ACCOUNTABILITY OFF., GAO-16-37, CLIMATE INFORMATION: A NATIONAL SYSTEM COULD HELP FEDERAL, STATE, LOCAL, AND PRIVATE SECTOR DECISION MAKERS USE CLIMATE INFORMATION 15 (2015).

277. *Id.* at 40.

278. STAFF OF H. SELECT COMM. ON CLIMATE CRISIS, 116TH CONG., REP. ON SOLVING THE CLIMATE CRISIS 37, https://docs.house.gov/meetings/CN/CN00/CPRT-116-CN00-D001.pdf [https://perma.cc/QJ6X-J6XG].

private-sector decision-makers."[279] The second, an interagency working group on Climate Risk Information, would "coordinate development of authoritative planning-scale climate risk information across federal civilian science departments and agencies and unclassified programs within defense and intelligence agencies."[280]

In the following Section, I seek to highlight key considerations that have been underexplored in climate services debates so far. Questions about methodological rigor, for example, are not only relevant when we consider what information the government provides to users, but also what information the government itself relies upon when crafting policies. While it is a potentially limited matter of consumer protection when a consultancy over-promises its analytical capabilities, it is a much larger problem if regulators misunderstand the limits of uncertainty when designing risk oversight. In Section 2, I turn to the question of what form the federal government's outward-facing climate services programs should take. Increased provision of downstream, location-specific, climate risk information is needed to address inequalities of access to climate services. Experts have debated the pros and cons of a centralized, "top-down" model versus a more networked approach that could draw on local expertise.[281] I advocate for a blended approach.

1. Internal Federal Climate Services

At this moment, many agencies across the federal government are scrambling to get up to speed on understanding and managing our climate changed future. The OCC, the SEC, the FIO, and the FHFA are just a few that have announced new climate mandates—all with little in-house staff capacity or expertise on the matter.[282] And yet these agencies are all about to face very similar questions and problems around data and models. Certain concerns

279. *Id.* at 375–76. ("To ensure that the best available scientific, economic, and social assessments inform Climate Risk Information Service products, the Service should work directly with the proposed interagency working group on Climate Risk Information. The Service should also partner with non-science federal agencies and with non-governmental groups, such as SCAN, to ensure that the development of risk information products occurs in close coordination with user and community needs.").

280. *Id.* at 375 ("The working group would complement existing efforts through the White House National Science and Technology Council Subcommittee on Global Change Research, which manages USGCRP, and the FGDC, and it would build on partnerships with nonfederal entities, such as through CDI and ESIP.").

281. *See, e.g.*, U.S. GOV'T ACCOUNTABILITY OFF., *supra* note 275, at 276.

282. One recent exception to the lack of scientific staffing is the hiring of Dr. Nina Chen to serve as Chief Climate Risk Officer in charge of the OCC's new Office of Climate Risk. Vanderford, *supra* note 32.

about methodological rigor and reliability of climate projections must be resolved to design functional rules and policies. What we can know about future risk matters for how the SEC structures the form and enforcement of corporate disclosures. It matters similarly for FHFA's oversight of Fannie Mae and Freddie Mac. The urgency of action is evidenced by the growing number of financial experts warning that markets on their own are not accounting for climate risks.[283]

Treasury's establishment of a Climate Data and Analytics Hub is in keeping with the NGFS's recommendation for regulators to "collaborate to bridge the data gaps to enhance the assessment of climate-related risks" [284] As Hilary Allen has pointed out, Treasury's Office of Financial Research ("OFR") is a natural home for the new Hub.[285] The OFR, created in the wake of the 2008 financial crisis was designed to be an "early warning system for emerging systemic risks" and part of its mission was to address "[g]aps in data availability and analysis."[286] Allen points out that the most important emerging systematic risks—she names climate change and fintech innovation—require expertise that is in extreme demand from the private sector, commanding high salaries and making hiring hard.[287] Rather than have each agency compete with one another for climate experts and data scientists, it makes sense for expertise and resources to be shared between agencies.[288]

Climate risk stress tests and regulations from the European Central Bank, the Bank of England, and the NGFS itself, have been subject to critique for their application of climate model outputs, or lack of precision.[289] The same methodological flaws practiced by many private sector actors, described *supra*, are simultaneously being employed some of the central banks leading in this area. The NGFS climate scenarios are generated by top-down economic models that simply assume a stable relationship between average global or regional warming levels and climate impacts experienced at specific

283. *See, e.g.*, Dennis Sugrue, *Global Reinsurers Grapple with Climate Change Risks*, S&P GLOBAL RATINGS (Sept. 23, 2021), https://www.spglobal.com/ratings/en/research/articles/210923-global-reinsurers-grapple-with-climate-change-risks-12116706 [https://perma.cc/C55M-EV5U]. *See generally* Madison Condon, *Market Myopia's Climate Bubble*, 1 UTAH L. REV. 63 (2022) (summarizing empirical, theoretical, and anecdotal arguments regarding climate related asset mispricing).

284. *Open Letter on Climate-Related Financial Risks*, BANK OF ENG. (Apr. 17, 2019), https://www.bankofengland.co.uk/news/2019/april/open-letter-on-climate-related-financial-risks [https://perma.cc/5ZUS-Y9KY].

285. Hilary J. Allen, *Resurrecting the OFR*, 45 J. CORP. LAW 1, 24–25 (2022).

286. *Id.* at 2.

287. *Id.*

288. *Id.* at 24.

289. Mackenzie, *supra* note 47; Pitman et al., *supra* note 23; Fiedler et al., *supra* note 24.

locations.[290] For its 2021 economy-wide stress tests, the ECB attempted a more bottom-up approach, using climate hazard data from the WMO, flood risk modeling firm Fathom, and Four Twenty Seven (which in turn used downscaled climate data provided by NASA).[291] More precise hazard data is only part of the challenge, however, as the ECB demonstrated by using the postal address of corporations' headquarters to determine climate risk exposure.[292] This approach, adopted due to lack of more comprehensive geospatial data, ignores risks to supply chains and all facilities like "plants, distribution hubs, and data centers."[293]

In its new Pilot Climate Scenarios Analysis, the Fed borrows from the NGFS scenarios and general approach to bank transition risk. But—perhaps because of critiques of "top-down" models and their focus on chronic risk—departs from the NGFS scenarios for physical risk. The large hurricane is one of two climate-related shocks banks are expected to model, with discretion given to their choice of second hazard. While consideration of acute risks is an improvement over top-down scenarios that neglect them, it is not clear that the Fed's limited exercise really captures the financial risks we should be worried about, including compounding, cascading, and correlated risks.[294] A KPMG Risk Management expert commenting on the new Fed scenarios argued that it was wise to focus on acute rather than chronic risks, as banks have demonstrated their ability to respond to gradual climate changes over the past 1.2°C of warming.[295] But the division between chronic and acute risks can be misleading: gradual changes in the environment can cross a real-

290. Monasterolo et al., *supra* note 119. *See, e.g.*, EUROPEAN CENT. BANK, OCCASIONAL PAPER SERIES: ECB ECONOMY-WIDE CLIMATE STRESS TEST 12–14 (2021), https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op281~05a7735b1c.en.pdf [https://perma.cc/ECU6-J7NY].

291. Downscaled data from NASA was used to predict wildfire, temperature, and precipitation risk indicators. The indicators for hurricane and flood risk were based on a more bottom-up approach, with hurricane risk based on historic hurricane exposure (with data from the WMO) and flood risk provided by Fathom, a leading flood catastrophe analytics firm. EUROPEAN CENT. BANK, CLIMATE-RELATED RISK AND FINANCIAL STABILITY: DATA SUPPLEMENT 13–14 (2021), https://www.esrb.europa.eu/pub/pdf/recommendations/2021/esrb.climateriskfinancialstability202107_annex~35e1822ff7.en.pdf [https://perma.cc/29VS-F5D4].

292. ECB ECONOMY-WIDE CLIMATE STRESS TEST *supra* note 290, at 25.

293. CLIMATE-RELATED RISK AND FINANCIAL STABILITY: DATA SUPPLEMENT, *supra* note 291, at 5, 8; Louie Woodall, *Here's How to Run Asset-Level Climate Physical Risk Assessments*, MANIFEST CLIMATE (May 19, 2022), https://www.manifestclimate.com/blog/heres-how-to-run-asset-level-climate-physical-risk-assessments/ [https://perma.cc/YYN3-NJGZ].

294. Bressan et al., supra note 70; Kruczkiewicz et al., *supra* note 70.

295. The Fed's Climate Scenarios Analysis, Audio Event (Feb. 10, 2023), notes from Mark Cliffe on file with author; *see also* Mark Cliffe, *The Fed's Climate Complacency*, PROJECT SYNDICATE (Feb 7, 2023), https://www.project-syndicate.org/commentary/federal-reserve-climate-scenario-planning-falls-short-by-mark-cliffe-2023-02 [https://perma.cc/6RR7-JXZB].

world threshold that manifests as acute risk. This happens when infrastructure designed to be resilient up to a certain temperature or precipitation-level breaks under a new climate-induced extreme. Chronic and acute risks also interact: a hurricane becomes more devastating when the seas are higher. While the Pilot's regional approach is just a first step, it is worth underscoring something that it crucially ignores: increasing geographical correlation.[296] Climate change is simultaneously making coastal flooding worse on the East Coast, just as it makes river-induced flooding worse in the Midwest, and wildfire damage worse in the West. And we should worry about the accumulative effects of these hazards eating away at the institutions and infrastructures our economy depends upon for resilience—including, but not limited to, municipal bond and insurance markets.[297] The Federal Reserve's physical risk Pilot frustrated climate scientists with its misunderstandings of the limits of climate forecasting on complex hazards far in the future.[298] Their objection raises the question: Why are we focusing on far-away, challenging-to-model risks, rather than the near-term hazards over which we have more scientific certainty?

In keeping with regulatory practice, the Fed defers to the banks' own modeling of the likelihood of future hazards under climate conditions.[299] However, given the above outlined challenges in climate models, regulators should question whether they want to depend upon the physical risk modeling performed by the banks (or their model provider(s)) and ratings agencies. The ubiquitous use of one model can magnify its blind spots.[300] Instead, this Article argues that U.S. financial regulators must develop long-lasting collaborative relationships with existing agencies staffed with environmental expertise. NOAA, EPA, USGS, and other non-financial agencies have a wealth of climate data and scientific knowledge, yet at the time of writing, the collaboration between these agencies and the financial regulators is

296. *See, e.g.*, Avery Ellfeldt, *Explaining the Fed's Climate Test*, E&E NEWS (Feb. 9, 2023), https://www.eenews.net/articles/explaining-the-feds-climate-test/ [https://perma.cc/WP8K-WX5M].

297. *See, e.g.*, Jesse D. Gourevitch et al., *Unpriced Climate Risk and the Potential Consequences of Overvaluation in US Housing Markets*, 13 NATURE CLIMATE CHANGE 250 (2023).

298. R. Saravanan, *Hurricane Fed*, *supra* note 63.

299. Graham S. Steele, *Confronting the "Climate Lehman Moment": The Case for Macroprudential Climate Regulation*, 30 CORNELL J. L. PUB. POL'Y 110, 153 (2020) (describing that regulators traditionally defer to the credit and business decisions of banks while ensuring that they have risk management protocols in place).

300. Fiedler et al., *supra* note 24, at 90–91 ("[P]oor use of science can exaggerate financial implications and either introduce a problem where none previously existed or provide false reassurance that there is no exposure to climate risk or that it is adequately addressed.").

limited. A centralized Climate Services hub could serve as the link between the OFR and the various climate-related agencies.

It is not just financial regulators that need information on future climate risk. Climate change projections should play a far broader role in government programs across the board. Oversight of toxic waste and industrial sites? Allocation of federal grants for infrastructure? Labor safety rules? It is difficult to think of an agency that will not need to consider the impact of extreme events and disruption in the decade ahead. Thus far, there has been an over-emphasis on providing risk information and not enough on proactive adaptive resilience responses.[301] Certainly, part of why insurance companies have been pushing to map more risk is to increase demand for their business. In the short term this is perhaps not a bad thing, in 2021 only 22% of losses were insured.[302] But we cannot insure our way out of the climate crisis – there is a limited amount that risk-sharing can do. Progress on modeling climate impacts must be driven a national interest in long-term adaptation; the insurance industry cannot be relied upon as the driver of innovation.

2. Outward-Facing Climate Services

In October 2021, the Biden administration announced its launch of a "whole-of-government initiative" to deliver user-friendly climate information.[303] The release points to two reports, one on improving climate services for the public, and the other on enhancing national geospatial capabilities for adaptation.[304] Both reports highlight pursuing public-private

301. *The Physical Risk and for the Climate Adaptation Summit*, TCFD, UNEPFI AND THE GLOB. CTR. ON ADAPTION (Jan. 25 2021), https://www.unepfi.org/wordpress/wp-content/uploads/2021/01/PRRC-Statement_CAS2021.pdf [https://perma.cc/M6JQ-P9AG] ("It is only in creating a market-wide, evidence based, comparable and standardised approach on physical climate risk that the financial sector will be able to price climate risk, thus building finance sector resilience and helping us to identify where and how our economy and society need to adapt to a changing climate.").

302. *Flood Risk: Underestimated Natural Hazards*, MUNICHRE https://www.munichre.com/en/risks/natural-disasters-losses-are-trending-upwards/floods-and-flash-floods-underestimated-natural-hazards.html [https://perma.cc/XKK4-DQRS].

303. *FACT SHEET: Biden Administration Makes Climate Information and Decision Tools More Accessible*, *supra* note 41.

304. OFF. OF SCI. & TECH. POL'Y ET AL., *supra* note 41; *Advancing the Nation's Geospatial Capabilities To Promote Federal, State, Local, and Tribal Climate Planning and Resilience: A Report to the National Climate Task Force*, FED. GEOGRAPHIC DATA COMM. (Oct. 2021), https://www.fgdc.gov/resources/key-publications/2021-climate-mapping-report/fgdc-climate-mapping-report-oct-2021.pdf [https://perma.cc/AYP5-PJ6L].

partnerships as a priority.[305] The following year, the website Heat.gov was unveiled: an information hub on climate change and extreme heat with interactive maps displaying forecasts, disparate impacts on environmental justice communities, health information, and more. The project had been years in the making, drawing together datasets from eleven different federal agencies.[306] The site itself was built by a private federal contractor, as, according to the head of the White House Climate Office, "[i]t's not easy [for the federal government] to put together such a portal."[307] The site is primarily pitched to community-level decisionmakers to aid with problems such as prioritizing investment into adaptation. While the data is open access, the site is not particularly user-friendly for individuals, and an agency head said that "he could imagine [private] 'added value service providers' using Heat.gov's data to create an app."[308]

Climate adaptation expert Alice Hill has written about the information deficit that individuals and communities face when trying to make decisions potentially impacted by climate change.[309] As described above, access to information about localized climate risk from sophisticated models is expensive, and unregulated. Hill argues for "a broader, open shift to apply science to local climate adaptation" in which the government works with both academia and the private sector to develop "publicly available models and tools to give decision-makers basic information at the scale they need."[310] The California Coastal Commission's environmental justice commissioner, Effie Turnbull Sanders, has spoken on the importance of climate risk tools:

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305. *Id.* (pointing to the Geospatial Data Act of 2018, which encourages agencies to partner with the private sector, and states that they "may, to the maximum extent practical, rely upon and use the private sector in the United States for the provision of geospatial data and services"); FED. GEOGRAPHIC DATA COMM., *supra* note 173, at 4; 43 U.S.C. § 2806 (2020). Journalists noted the Biden Administration's shift away from the centralized NCS idea in favor of "agency-to-agency partnerships as well as private sector engagement" in its climate information agenda. *See, e.g.*, Andrew Freedman, *Biden White House Launches "Climate Services" Push, Revamps Climate.Gov*, AXIOS (Oct. 13, 2021), https://www.axios.com/2021/10/12/biden-administration-launches-climate-services-push [https://perma.cc/EEP8-65EE].

306. Press Release, U.S. Dep't of Com., *Biden Administration Launches Heat.Gov with Tools and Information for Communities Facing Extreme Heat*, (July 26, 2022), https://www.commerce.gov/news/press-releases/2022/07/biden-administration-launches-heatgov-tools-and-information-communities [https://perma.cc/52CE-7HF7].

307. Alex Woodie, *Esri Puts Federal Climate Change Action on the Map*, DATANAMI (July 13, 2022), https://www.datanami.com/2022/07/13/esri-puts-federal-climate-change-action-on-the-map/ [https://perma.cc/3XK5-33B2].

308. Lisa Martine Jenkins, *The Biden Administration Launches New Extreme Heat Site*, PROTOCOL (July 26, 2022), https://www.protocol.com/bulletins/extreme-heat-weather-noaa-site [https://perma.cc/ZCF9-94LW].

309. Hill, *supra* note 28, at 9.

310. Hill, *supra* note 28, at 9.

"The more data we have, the more opportunity we have to disrupt the status quo and paint a picture that truly exposes the discriminatory land-use policies of the past — and those that continue into the future."[311]

An outward-facing National Climate Service could address, in some measure, these inequalities of data access. An NCS could serve as a public option, alongside the ever-evolving private climate services sector.[312] Public options can serve to balance between the "urgent need for greater equality and the benefits of markets."[313] At-risk communities and small businesses that cannot afford the high price tag of consultancy services could turn to the NCS for support. Low-income communities are exposed to disproportionately high levels of risk from climate change, exacerbated in part by an inability to access resources and information.[314] Investment in the NCS would strengthen governments' own climate planning capacities, with spillover benefits to all regulators and others that rely on cutting edge climate science.

U.S. government climate scientists are some of the most expert and well-resourced in the world—producing and maintaining several large global climate models. However, existing agencies are failing to keep up with the growing demand for translation and application of these models for specific end-users. Because federal agencies must allocate budgetary resources subject to mandate, NOAA is impeded from reorganizing on its own and re-prioritizing the provision of downstream climate services. The federal funding of academic climate research similarly "does not readily support and sustain research-to-operations efforts."[315] The parts of the government we do rely upon to provide public information on weather and climate risks are sorely in need of additional funding.[316] National Weather Service employees submitted evidence to Congress of over-work and understaffing "[d]espite an

311. Xia, *supra* note 53.

312. Ganesh Sitaraman & Anne L. Alstott, *There Should Be a Public Option for Everything*, N.Y. TIMES (July 6, 2019), https://www.nytimes.com/2019/07/06/opinion/sunday/public-option.html [https://perma.cc/7KKL-PGDZ]; *see also* GANESH SITARAMAN & ANNE ALSTOTT, THE PUBLIC OPTION: HOW TO EXPAND FREEDOM, INCREASE OPPORTUNITY, AND PROMOTE EQUALITY (2019).

313. *Id.*

314. Michelle Zaludek, *Surviving Climate Change: An Examination of Government Disaster Response and its Effect on People Impacted by Poverty*, 31 ALB. L.J. SCI. & TECH. 226, 228 (2021).

315. Wright, Samaras, & Lopez-Cantu, *Resilience to Extreme Rainfall Starts with Science*, 102 BULL. AM. METEOROLOGICAL SOC'Y E808, E811 (Apr. 2021).

316. *Confronting Climate Impacts: Federal Strategies for Equitable Adaptation and Resilience: Hearing Before the H. Select Comm. on the Climate Crisis*, 117th Cong. 7 (2022) (statement of Dr. Lara Hansen, Chief Scientist and Executive Director at EcoAdapt) (reporting that climate risk interfaces provided by federal agencies, such as the Climate Resilience Toolkit and EPA's ARC-X, "are a great start but are all wildly underfunded to meet the need").

ever-expanding mission, increasing decision support responsibilities, and growing frequency of flooding and hazardous weather events."[317]

One of the most serious critiques against a new NCS is the concern that a top-down, centralized service cannot possibly meet the needs of the varied users across the many geographies of the United States.[318] One expert has argued that a "national climate information system with defined roles for federal agencies" would be preferable to a new NCS, in part because no "single institution or program will be able to meet all user needs."[319]

For this reason, the approach to outward-facing climate services should adopt a hub and spokes model, with regional centers devoted to supporting the surrounding community. Climate scientist Bob Kopp has suggested that the existing U.S. land grant university network could be built upon for developing and disseminating public climate services[320] There is evidence suggesting that drawing from a local knowledge base is crucial for climate risk assessment. For example, Jesse Keenan has done research on information asymmetries between local banks and larger lenders or GSEs.[321] According to Keenan, local banks, which tend to be smaller and more concentrated in specific geographic areas, have access to relevant climate information specific to their region.[322] This climate "data" can come in the form of what Keenan calls "soft information," like individual human memory of recent

317. *Future of Forecasting: Building a Weather-Ready Nation on All Fronts: Hearing Before the H. Comm. on Space, Sci., & Tech.*, 117th Cong. 1 (2021) (statement of John Werner, President, National Weather Service Employees Organization). Werner's testimony also informs that "[i]n May 2017, the GAO released a study requested by Members of the House Science Committee which revealed that the vacancy rate in NWS operational units has reached a point where NWS employees are 'unable at times to perform key tasks' [and] 'experienced stress, fatigue and reduced morale resulting from their efforts to cover for vacancies.'" *Id.* at 2.

318. *See Working Towards Climate Equity: The Case for a Federal Climate Service: Hearing Before the H. Comm. on Sci., Space & Tech., Subcomm. on Env't*, 117th Cong. (2021) (statement of Dr. Richard H. Moss, Senior Scientist, Joint Global Change Research Institute), https://www.congress.gov/117/meeting/house/112483/witnesses/HHRG-117-SY18-Wstate-MossR-20210421.pdf [https://perma.cc/P5YD-ERN7] ("There is an urgent need for a federally supported national system or framework for climate information that establishes leadership, coordination, and accountability across diverse actors to provide users with accessible and authoritative information and responsive technical assistance.").

319. *Id.* at 6.

320. *See generally* Kopp, *supra* note 267, at 28. For example, the EU Horizon 2020 Programme issues competitive grants for public sector climate services research and development, including for the creation of hub structures to bring together "service products, providers, and users." STEGMAIER & PERRELS, *supra* note 54 at 25.

321. Jesse M. Keenan & Jacob T. Bradt, *Underwaterwriting: From Theory to Empiricism in Regional Mortgage Markets in the U.S.*, 162 CLIMATIC CHANGE 2043, 2047 (Oct. 2020).

322. *Id.* at 2048 ("In theory, local concentrated lenders should be able to source more precise information about pricing signals, local environmental exposures and local hazard mitigation and adaptation efforts.").

natural disasters, or personal knowledge of coastal geographies and construction material.[323] This "soft information" can be extremely localized and therefore superior to the large-scale top-down climate hazard models employed by larger diversified banks and the federal government.[324]

Drawing from local knowledge is important for more than finding the right data for climate modelers. Ample evidence shows that getting communities on board with adaptation projects requires involving them in decision-making and planning processes.[325] Translating climate risk assessment to lay people is a challenge, but the lack of clear explanations and transparency can lead to distrust.[326] Access to climate risk tools may be able to facilitate engagement not only in adaptation projects but the broader issue of climate change. As one expert has quipped: "[A]daptation is the gateway drug to mitigation… once you see how big the problem will be for your community [you realize i]t would be a hell of a lot easier to just stop emitting carbon dioxide into the atmosphere."[327]

B. Open Climate Data & Disclosure

At her testimony to the House Subcommittee on Financial Protection, Heather McTeer Toney reported that during her tenure as mayor of Greenville, Mississippi, the city experienced two separate "500-year flood events."[328] Both caused extensive damage to the city's infrastructure, including its bridges, roads, and water system. McTeer Toney testified that Mars Foods, Inc., which operated Ben's Original Rice in Greenville, was a crucial partner in her city's ability to meet increasing climate risks: "Their willingness to not only assess climate risk, but share the information, meant that I was prepared to account for the necessary support: street upgrades; police and fire in case of emergency; water system points of weakness; potential levee breaches; and places to point the Army Corps of Engineers for review."[329]

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323. *Id.* at 2047.

324. *Id.* at 2057.

325. Charles Herrick & Jason Vogel, *Climate Adaptation at the Local Scale: Using Federal Climate Adaptation Policy Regimes to Enhance Climate Services* 14 SUSTAINABILITY 8135 (2022); Eva Boon et al., *Successful Climate Services for Adaptation: What We Know, Don't Know and Need To Know*, 27 CLIMATE SERVICES (2022); Adam Minter, *Kansas Is Showing What a Drier Future Looks Like*, BLOOMBERG (Mar. 12, 2012).

326. Boon et al., s*upra* note 325, at 9.

327. Ostrander, *supra* note 68.

328. *Helping Corporate Boards and Investors*, *supra* note 229 (statement of McTeer Toney).

329. *Id.*

The preceding Part noted that Moody's Four Twenty-Seven had published a detailed analysis of climate-related flood risks on the asset price of REITs, including investigation into adaptation measures undertaken (or not). Were the residents and renters of these buildings informed? What about their neighboring buildings? While Mars Foods chose to share risk information—likely because it was in the companies own interest to see that roads were kept operational—it was not obligated to do so. Is this cutting-edge data being used in the best way; could it be used to mitigate risk, for more people, rather than hedge it for some?[330]

In the European Union, policymakers seeking to promote the production and use of climate services have explicitly framed their policy options as potentially falling under three different "governance approaches": state-centered, business-centered, or network-centered.[331] Under this framework, the "state-centered scenario" envisions strong public interventions with an emphasis on equity, safety, and societal resilience. The "business-centered" scenario rests on a belief in free markets and innovation, with a "limited" role for public services, including the provision of climate change scenarios and "basic data." The third scenario, "network-centered," emphasizes that climate adaptation is a local issue that must be met by ground-up expertise and consultation.[332]

This framing is useful, but its version of "state-centered" climate services looks mostly just like a National Climate Service that crowds out the competitors. Chris Morten has pointed out that alongside the U.S. government's commitment to "open data" initiatives, federal agencies have simultaneously trended towards disclosing less corporate information to the public.[333] He points out that expansion of "open access" to government information generated by public resources can be a gift to those very corporations that criticize government research. This gift is received without any expectations of reciprocal sharing of corporate information to the public.[334]

This Article advocates for a centralized National Climate Service tasked with informing outward-facing adaptation decisions and inward-facing regulatory decisions. However, this "state-centered" approach should be expanded to include more aggressive publication of corporate information

330. *See* Taylor, *supra* note 30, at 1142 (arguing the reinsurance industry in South Florida simply transfers risk, rather than mitigating it, inevitably propagating total systemic risk).

331. STEGMAIER & PERRELS, *supra* note 54, at 54.

332. *Id.*

333. Christopher Morten, *Publicizing Corporate Secrets for Public Good*, 171 UNIV. PENN. L. REV. 25 (forthcoming 2023).

334. *Id.*

related to climate risks. This approach can be many-faceted and follow several legal routes. As explained by Morten, agencies have broad discretion to publicize information they obtained from regulated corporations so long as it serves the public interest.[335] Further, a range of existing disclosure laws can be expanded to either explicitly include climate information or require more detail on modeling inputs and assumptions.

Heather McTeer Toney testified to Congress that "[s]trengthening [corporate] climate risk disclosure is a necessity for more than markets and investors."[336] Toney, however, was before the House Committee on Financial Services, debating disclosure in the securities context. The SEC's disclosure mandate rests on its mission of investor protection and efficient markets. The agency is tasked with designing disclosure standards with these users in mind, not communities. Similarly, the Federal Insurance Office's proposed call for data from property and casualty insurers is aimed at assessing the availability and accessibility of insurance, but its mandate and legal authority are limited by the country's traditional state-level approach to insurance regulation.[337] The National Association of Insurance Commissioners is fighting the data call, arguing that insurers data analysis "will be misinterpreted and produce fallacious results in trying to identify climate risk.'"[338]

Financial institutions' own climate risk models will inform their risk management and loss reduction strategies.[339] Shortened investment horizons and higher discount rates in real-estate finance will combine with higher insurance premiums or withdrawal of coverage to depress property values "long before rising seas permanently breach property lines."[340]At present, environmental justice and academic researchers are racing to understand the combined impacts of both climate change *and* the financial sector's response to climate risk. The models used by Moody's to assess municipal bond risk

335. *Id.*

336. McTeer Toney, *supra* note 2, at 2.

337. *Treasury's Federal Insurance Office Takes Important Step To Assess Climate-Related Financial Risk – Seeks Comment on Proposed Data Call*, U.S. DEP'T TREASURY, https://home.treasury.gov/news/press-releases/jy1030 [https://perma.cc/R7MQ-4WTA]; National Association of Insurance Commissioners, *Federal Insurance Office (FIO)*, https://content.naic.org/cipr-topics/federal-insurance-office-fio [https://perma.cc/9QCS-66CB].

338. Chad Hemenway, *NAIC Adds "Deep Concerns" to FIO Bid To Collect Climate Change Data From Insurers*, INS. J., https://www.insurancejournal.com/news/national/2022/11/23/696462.htm [https://perma.cc/7FQ2-UJ66].

339. Taylor & Aalbers, *supra* note 26, at 1689.

340. *Id.* at 1686.

might determine whether a town can borrow to pay for sea wall.[341] Or whether gentrification trends are accelerated by higher insurance rates.[342] Zac Taylor and Manuel Aalbers have argued that lack of access to "granular and open-source climate and catastrophe risk models, and neighborhood-level insurance underwriting data" is a major impediment to progress in this area.[343] Aalbers and Taylor suggest that existing fair housing finance data disclosure requirements should be expanded to include access to underwriting data.[344] This requirement could address one of the many existing information asymmetries of climate information. The insurers with the best access to location-specific risks price premiums on an annual basis; the risk models reviewed by state insurance regulators are those used to price one-year policies.[345] While an insurer might have access to information that premiums might become unaffordable in certain neighborhoods in a decade, the only requirement to share this information with outsiders comes in the form of the securities regulations, which are not particularly rigorous when it comes to specifying the disclosure of forward-looking physical climate risk.

So far, Biden's "whole-of-government" approach to climate change has emphasized emissions reductions and transition risks, with less attention—and resources—paid to adaptation and physical risks. But the government's approach to climate information does not need to be driven by the concept of financial risk, rather than general national resilience. Agency experts on market mispricing and systemic risks do not overlap with agency experts on adaptation deficits and infrastructure planning. Yet these concerns enforce one another. Lower income and communities of color are likely to be disproportionately affected by market-rate based responses to climate risk.[346] Activists caution that financial regulators must consider these disproportionate spillover effects of their policies. Yet when the New York State Department of Financial Services proposed climate risk guidance that reminded banks of their obligations existing anti-redlining law, there was pushback. One law firm implied that asking the banks to manage climate risk

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341. Christine Sgarlata Chung, *Rising Tides and Rearranging Deckchairs: How Climate Change Is Reshaping Infrastructure Finance and Threatening To Sink Municipal Budgets*, 32 GEO. ENV'T L. REV. 165, 193, 206 n.202 (2020).

342. *See generally* Taylor & Aalbers, *supra* note 26, at 1695–97.

343. *Id.* at 1697.

344. *Id.*

345. *Id.* at 1688–89.

346. Peace Gwam, Ananya Hariham & Carlos Martín, *Federal Disaster Policy Reforms—Including Flood Insurance Treatment—Should Center Racial and Economic Equity*, URBAN WIRE (Sept. 30, 2020), https://www.urban.org/urban-wire/federal-disaster-policy-reforms-including-flood-insurance-treatment-should-center-racial-and-economic-equity [https://perma.cc/KN9N-BSGE].

and their Community Reinvestment Act ("CRA") obligations was imposing a conflicting mandate.[347] Proposed changes to the Federal CRA encourage banks to fund climate resilience projects in low-income communities but give little guidance about evaluating or prioritizing adaptation projects.[348] If people get priced out of their homes, where will they go? Questions about insurance pricing and oversight of mortgage lending reveal the need for a nationwide coordinated plan for climate adaptation and managed retreat. Such a plan clearly requires considerations beyond financial risk exposure. Yet, unlike other countries, the U.S. lacks a coordinated adaptation plan.[349]

In 2018, it was revealed that Amtrak had hired Booze Allen Hamilton to complete a multi-year climate study, the conclusion of which was that stretches of the Northeast Corridor would face "continual inundation" due to sea-level rise over the next three decades.[350] The report zoomed-in to focus on a ten-mile stretch of track in Delaware at extreme risk, where median projections indicate two feet of sea level rise by 2050. The report suggested temporary protection measures costing more than $100 million. As an investigation by Bloomberg revealed, Amtrak did not share the report with the mayor of Wilmington, where the track section was centered, nor the Governor of Delaware, nor the Northeast Corridor Commission, whose role is to facilitate "collaborative planning" between Amtrak, the federal government, and the states.[351] Amtrak also declined to follow one of the key recommendations of the report: to repeat the analysis on other sections of track.[352]

CONCLUSION

In March 2022, Commissioners at the SEC voted 3-1 to propose a rule mandating a broad range of climate-related disclosures from public corporations. Hester Peirce, the lone Republican Commissioner, issued a long

347. Matthew Bisanz, Tori K. Shinohara & Kris D. Kully, *Climate Risk Management vs. Community Development Lending: NYDFS Wants its Banks and Mortgage Companies To Do Both*, MAYER BROWN (Jan. 3, 2023), https://www.mayerbrown.com/en/perspectives-events/publications/2023/01/climate-risk-management-vscommunity-development-lendingnydfs-wants-its-banks-and-mortgage-companies-to-do-both [https://perma.cc/M3XX-JNNE].

348. *See, e.g.*, Sam Whillans, *Banking Regulators Confront the Green Resilience Paradox*, ABA TRENDS (Mar. 3, 2023), https://www.americanbar.org/groups/environment_energy_resources/publications/trends/2022-2023/march-april-2023/banking-regulators/ [https://perma.cc/SV54-U2FL].

349. *See, e.g.*, INDEPENDENT ASSESSMENT OF UK CLIMATE RISK, *supra* note 63.

350. Flavelle & Lin, *supra* note 29.

351. *Id.*

352. *Id.*

dissent, later titled "We Are Not the Securities and Environment Commission."[353] Among a host of her concerns about the rule, Peirce pointed to the rule's guidance that "climate consulting firms are available to assist registrants" in identifying material climate risks.[354] "Score one for the climate industrial complex!" she quipped (with her camera off, to save emissions).[355] The term "climate industrial complex" has a long history of use by climate skeptics and representatives of the right—nevertheless this Article argues that Commissioner Peirce has a point.

But this "climate industrial complex" started growing before the SEC's disclosure rule seemed politically possible; and it will continue to exist even if the Supreme Court decides to kill the rule. Its existence is not unrelated to the efforts to block and defund federal climate services over the last three decades. The National Climate Program Act originated because congressmen from both political parties felt that the Carter administration was failing to prioritize research on climate impacts and adaptation that could be used by the states.[356] The NCPA's primary sponsor argued the legislation was "especially important in that it will help bring the Federal involvement down to the local level and also provide a channel for information from users back into the program."[357] The NCPA's vision was never fully realized, in part because the Office of Management and Budget felt that the program was redundant to the existing, centralized, focus on atmospheric research, and a potential example of government inefficiency.[358]

We should not be surprised that the private sector is working to price climate risk, but we can wonder what a more robust and collaborative climate impact program might have changed about the response to Oregon's wildfire risk map. In the absence of public climate services, we have been left with little institutional capacity for adaptation. Florida officials are seeking to protect insurance companies from litigation to keep premiums down—just as they announce prohibitions on ratings agencies that use environmental factors to evaluate municipal bonds.[359] Libertarians call ESG investing "top-down

353. Commissioner Hester Peirce, *We Are Not the Securities and Environmental Commission – At Least Not Yet*, SEC (Mar. 21, 2022), https://www.sec.gov/news/statement/peirce-climate-disclosure-20220321 [https://perma.cc/X5EA-3STJ].

354. 87 Fed. Reg. 21334, 21351-52, *supra* note 34, at 75.

355. Peirce, *supra* note 353.

356. Henderson, *supra* note 270, at 232.

357. *Conference Report on H.R. 6669, National Climate Program Act*, 124 CONG. REC. 28119 (Sept. 6, 1978) (statement of Rep. George Brown (CA)).

358. Henderson, *supra* note 270, at 210.

359. Lawrence Mower, *Florida Lawmakers' Answer to Insurance Crisis: Make it Harder To Sue Insurers*, MIAMI HERALD (Mar. 14, 2023), https://www.miamiherald.com/news/politics-

planning by elites."[360] And angry homeowners are resorting to posting one-star Google reviews of First Street Foundation, complaining about faulty methods and lack of recourse to challenge their listing's Flood Factor™.[361]

government/article273107190.html; *Governor Ron DeSantis Announces Legislation To Protect Floridians from the Woke ESG Financial Scam* (Feb. 13, 2023), https://www.flgov.com/2023/02/13/governor-ron-desantis-announces-legislation-to-protect-floridians-from-the-woke-esg-financial-scam/ [https://perma.cc/A6NW-WYJR].

360. MATTHEW LAU, ESG IS MAINLY TOP-DOWN PLANNING BY ELITES FRASER INST. (2023).

361. Google Reviews for First Street Foundation, GOOGLE MAPS, http://maps.google.com (search First Street Foundation; then click on Reviews; then click Sort and choose lowest ratings).