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Capstone Project 2020

Adapting to Climate Change: A Look at Real Estate Developers and Investors

Project Advisor: David Sherman

Capstone Team: Binyu Zhao Masafumi Nojiri
Haozhi Zhang Rui Niu
Julian Gocksch Yue Wu

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Section 1: Introduction

Over the past several decades, scientific evidence of the warming of the climate system has become unequivocal. A recent report published by NASA and NOAA showed that the decade from 2010 to 2019 was the hottest on record since record keeping began 140 years ago. 2019 was the second-hottest year on record, and ocean temperatures are now the highest they have ever been.

As a result of these rising temperatures, sea levels are also rising at an astonishing rate. The extent to which sea levels will rise is disputed and unknown. The global mean sea level (GMSL) is expected to rise 0.3–0.6 feet (9–18 cm) by 2030, 0.5–1.2 feet (15–38 cm) by 2050, and 1.0–4.3 feet (30–130 cm) by 2100[1]. Although we don't know for sure that any major American cities will be underwater in our lifetimes, rising, warming seas lead to higher-impact storms and more frequent and severe flooding. As sea levels rise closer and closer to land level, property only a small height above sea level becomes more vulnerable to flooding, even from relatively small storms. We are already seeing this in the United States, nowhere more so than in Miami. Jupiter Intelligence, with data compiled by NOAA, estimates that, by 2050, annual flooding in Miami will double and 61% more properties will be at risk of chronic flooding than are currently at risk[2]. New modeling by non-partisan economic think tank Resources for the Future projects sea level elevation of between 8 and 12 inches by 2040. The implication of this outcome would be that nearly half a million Floridians who live less than 3 feet above sea level would be exposed to regular flooding, and about $145 billion in real estate value would be jeopardized[3].

The accelerated pace of climate change has manifested itself most demonstrably in the uptick in frequency and scale of natural disasters, particularly hurricanes. Hurricanes Katrina, Sandy, Maria, and Harvey left in their wake not just a trail of untold devastation and suffering to the communities they hit; these disasters caused considerable economic damage. Damage from Superstorm Sandy amounted to over $74 billion, mostly in the New York metropolitan area. The extreme winds, heavy rainfall and concurrent flooding from Hurricane Harvey left behind over $130 billion in damages in Houston and the surrounding areas. Hurricane Katrina was the most economically catastrophic storm in United States history, destroying large sections of the city of New Orleans, and damaging infrastructure worth over $170 billion[4].

One of the most exposed sectors to rising sea levels and climate change-related natural disasters is the commercial real estate industry. To understand how the sector can prepare for the future, we have conducted a capstone project to look at the ways in which the real estate community has been changing its business practices as a result of climate change, and in what ways it still needs to change. To do so, we first conducted a literature review of foundational works written on climate change risk assessment and potential impact on real estate and municipal infrastructure. We then interviewed key

[1] Usgcrp. (n.d.). Climate Science Special Report. Retrieved April 22, 2020, from https://science2017.globalchange.gov/

[2] Jupiter Intelligence Report on Miami-Dade Climate Risk. (2020, April 22). Retrieved from https://www.scribd.com/document/443190598/Jupiter-Intelligence-Report-on-Miami-Dade-Climate-Risk

[3] Florida Climate Outlook: Assessing Physical and Economic Impacts through 2040. (n.d.). Retrieved April 22, 2020, from https://www.rff.org/publications/reports/florida-climate-outlook/

[4] Adam.Smith@noaa.gov. (n.d.). Billion-Dollar Weather and Climate Disasters: Events. Retrieved April 22, 2020, from https://www.ncdc.noaa.gov/billions/events/US/1980-2017

experts and practitioners at 14 organizations who have hands-on experience and knowledge of current climate change adaptation practices with regard to future development plans, accountability to investors, and operations. Interviewees included real estate developers, investors, consulting and research firms, and government agencies. This paper - its outline of current practices and trends, conclusions, and recommendations - is the result of data and insights obtained from our review of existing literature on the topic and our canvassing of industry experts.

Section 2: Current Status of the Real Estate Industry

As the rising threat of climate change starts to pose a greater risk to assets, real estate investors and developers are taking note. Climate change has already done considerable damage to properties and led to significant property values losses in coastal communities. The industry recognizes that rising sea levels and extreme weather events are challenges that must be prepared for.

Mitigation vs Adaptation Responses

Methods of response to climate change fall into two broad categories: mitigation responses and adaptation responses. Mitigation responses are focused on the root of the problem. In the context of climate change, this means reducing carbon emissions to diminish the future effects. The Intergovernmental Panel on Climate Change (IPCC) defines mitigation as “human intervention to reduce the sources or enhance the sinks of greenhouse gases”. One of the most common mitigation responses is replacing greenhouse gas-emitting fossil fuels like coal, oil, and natural gas with clean, renewable energies like solar, wind, and geothermal. When it comes to the commercial real estate industry, a common mitigation measure is to reduce building carbon emissions by retrofitting buildings to include more energy-efficient lighting, HVAC systems, and water usage systems.

Adaptation, on the other hand, is addressing the effects of the problem, rather than the root of the problem. The IPCC defines adaptation as “the process of adjustment to actual or expected climate and its effects.” Adaptation strategies to protect urban real estate include building sea walls, elevating infrastructure, or retreating from low-lying coastal areas altogether. These types of adaptation responses are the focus of this capstone project.

Through the course of our research, we have found that the commercial real estate industry is currently taking more active mitigation measures than adaptation measures to address climate change. Many of the real estate development firms we interviewed issued an annual “sustainability report”, which outlined climate mitigation efforts almost exclusively. Some in the industry even seemed to conflate the two concepts. Interviewees spoke about reduction in greenhouse gas emissions and energy usage and about the waste diversion rate of commercial buildings. The design and operation of Leadership in Energy and Environmental Design (LEED)-certified buildings is increasingly prevalent. More commercial building developers are utilizing the Environmental Protection Agency’s Energy Star Portfolio Manager tool to measure and track energy use, water use, and material waste, and to ensure these buildings attain Energy Star certification.

These types of mitigation efforts, while notable and important, are not the focus of this project. This project studies adaptation efforts to deal with climate change as it stands today and the risks it poses for the future by protecting vulnerable assets in a tangible way. This is not to say nothing is being done on the adaptation side. Real estate developers, for instance, have been implementing new building design techniques to ensure the resilience of new developments to the risks of climate change. It is safe to say, though, that, based on interviewees' responses and the research conducted we have conducted, the focus of the industry is currently on the mitigation side of this issue.

Losses and Damages

The past decades have witnessed significant losses in the real estate market due to climate sea level rise, hurricanes and flooding. The losses can be categorized into two main types, property value loss and property damage.

- **Property Value Loss Due to Sea Level Rise**

  Evidence of the impact of rising sea level on real estate returns is slowly starting to emerge. A high-profile study by the University of Colorado at Boulder and Pennsylvania State University, published by the Journal of Financial Economics, found that properties exposed to sea level rise are now selling at a 7 percent discount relative to comparable but less-exposed properties across the nation. [5]Buyer behavior reflects the expense of frequent flooding and the threat of lower resale values in the future due to sea level rise. The experience in Miami is an early example of the vulnerability of housing markets in coastal cities. Zillow Research estimates that nationally, 1.9 million homes are projected to be literally

  underwater by the year 2100, causing losses of up to $1 trillion. Mortgage giant Freddie Mac is actively thinking about the implications of climate change for its book of business, and for loans extended to homes in flood-prone areas.[6] A paper by Piet Eichholtz[7] shows that commercial real estate values are affected strongly by fat-tail climate events such as Hurricane Sandy, although markets seem to return to "normal" after recent events fade from investors' memory. The value of real estate in coastal zones with a high risk of flooding may lag or decrease relative to property values in less flood-prone inland areas, according to an estimate in MSCI's "ESG Trends to Watch in 2019" Report.

[5] Bernstein, A., Gustafson, M., & Lewis, R. (2017). Disaster on the Horizon: The Price Effect of Sea Level Rise. SSRN Electronic Journal. doi: 10.2139/ssrn.3073842

[6] Bretz, L. (2018, January 18). Climate Change and Homes: Who Would Lose the Most to a Rising Tide? Retrieved April 22, 2020, from https://www.zillow.com/research/climate-change-underwater-homes-2-16928/

[7] "Where, When and How Do Sophisticated Investors Respond to Flood Risk?" by Piet M. A. Eichholtz, Eva Steiner et al. (2019). Retrieved April 22, 2020, from https://scholarship.sha.cornell.edu/workingpapers/51/

According to First Street Foundation[8], data gathered from the 18 states along the East and Gulf Coasts in the U.S shows that increased tidal flooding driven by sea level rise has eroded $15.9 billion in relative property values between 2005 and 2017. Among the 18 states analyzed to date, Florida has seen the greatest loss in relative value at $5.4 billion. A majority of the losses come from the residential sector due to the continued, sometimes irrational, desire of people to live in coastal areas and build waterfront houses. However, rising sea levels have already threatened the pricing and investing of commercial real estate as well in other places, such as Houston.

	State	Loss (Million)	Period
1	Florida	$ 5,400.0	2005-2017
2	New Jersey	$ 4,500.0	2005-2017
3	New York	$ 1,300.0	2005-2017
4	South Carolina	$ 1,100.0	2008-2017
5	Connecticut	$ 915.9	2005-2017
6	North Carolina	$ 582.3	2005-2017
7	Maryland	$ 555.7	2005-2017
8	Delaware	$ 299.5	2005-2017
9	Virginia	$ 280.3	2006-2017
10	Massachusetts	$ 273.4	2005-2017
11	Mississippi	$ 263.8	2005-2017
12	Alabama	$ 157.9	2005-2017
13	Texas	$ 76.4	2005-2017
14	Maine	$ 69.9	2005-2017
15	Rhode Island	$ 44.7	2005-2017
16	Georgia	$ 15.3	2005-2017
17	New Hampshire	$ 15.2	2005-2017
18	Pennsylvania	$ 10.1	2005-2017

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Figure 1: Property Value Loss Due to Sea Level Rise (2005-2017), Source: First Street Foundation

- **Property Value Loss due to hurricane and flooding**

Hurricane winds and storm-related flooding are responsible for the bulk of damage from disasters in the United States. Storm-related floods can have both direct and indirect impacts on buildings, as they can damage property and nearby infrastructure and disrupt operations, leading to a decrease in property value and rental price.

Williamsburg case study: Even though very few of the buildings in Williamsburg suffered direct damage from Superstorm Sandy in 2012, the indirect damage to the L train was very costly. Sandy's surge flooded the Canarsie Tunnel under the East River with millions of gallons of saltwater, causing severe damage. In response, the MTA said it would need to shut down the L

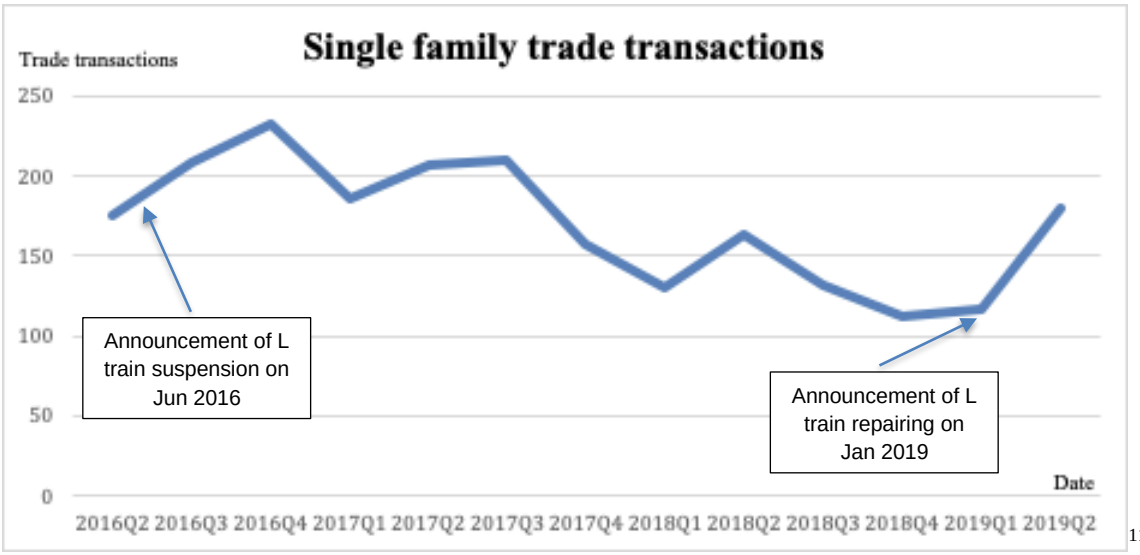
[8] Mcalpine, S. A., & Porter, J. R. (2018). Estimating Recent Local Impacts of Sea-Level Rise on Current Real-Estate Losses: A Housing Market Case Study in Miami-Dade, Florida. Population Research and Policy Review, 37(6), 871–895. Retrieved April 22, 2020, from https://doi.org/10.1007/s11113-018-9473-5

[9] Firststreet.org. (n.d.). Property Value Loss from Sea Level Rise State by State Analysis - First Street Foundation. Retrieved April 22, 2020, from https://firststreet.org/press/property-value-loss-from-sea-level-rise-state-by-state-analysis/

train between Manhattan and Brooklyn for 15 months beginning April 27, 2019, so that it could make critical repairs. The single-family median list price in Williamsburg began to dip almost immediately after Metropolitan Transportation Authority officials made the announcement in summer 2016. Single family housing transactions also declined for three months in a row after the announcement.

According to StreetEasy, the neighborhood's median rental price fell 8.3%, the largest drop recorded, to $3,000 in January 2017. The median rent slipped further to $2,899, its most recent lowest point, in December 2018. Clearly, Superstorm Sandy indirectly affected the real estate market in Williamsburg, especially for those who worked in Manhattan.[10]

A new proposal was announced in January 2019, which calls for crews to repair the Sandy-damaged Canarsie tunnel on nights and weekends, without completely shutting down service through Manhattan in April, as originally planned. This was a positive sign for the Williamsburg real estate market. Both single-family house transactions and median list price bounced back after the new plan was implemented.

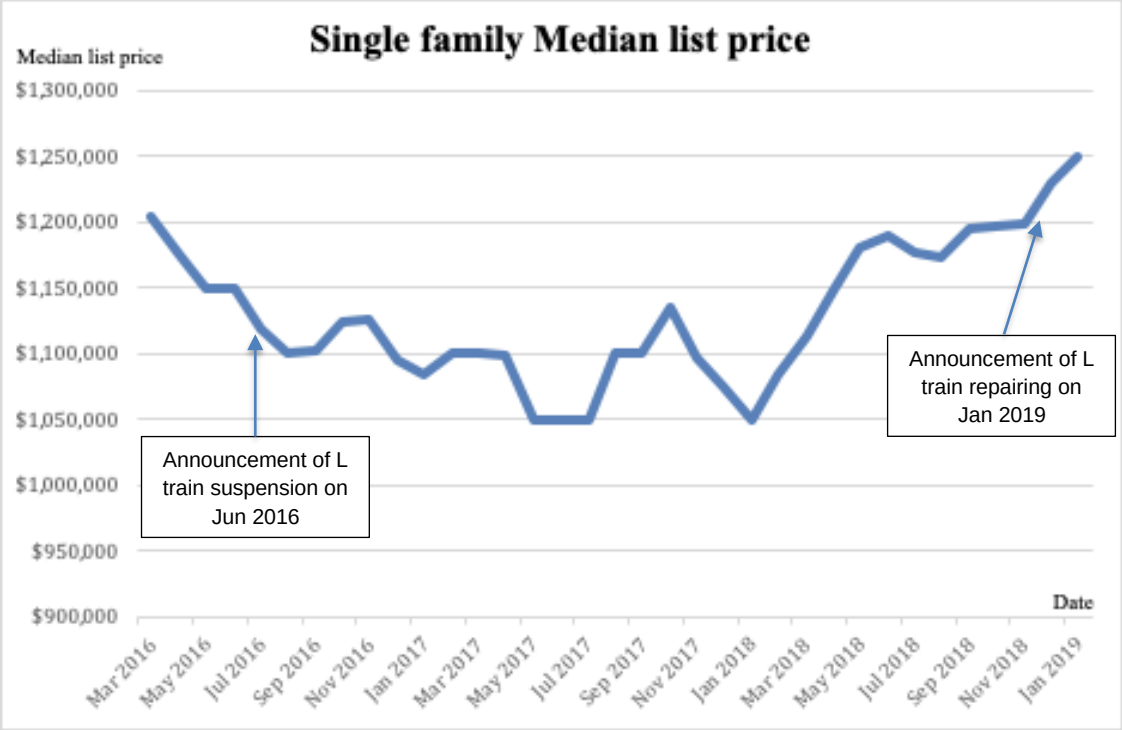


[11]

Figure 2: Williamsburg single-family building transaction (2016.4-2019.4) Source: Property Shark

[10]The L Shutdown Set Off a Bargain Hunt in Williamsburg. (2020, April 22). Retrieved from https://streeteasy.com/blog/l-shutdown-and-the-housing-market-williamsburg-greenpoint-brooklyn/

[11] "Williamsburg Real Estate Market Trends." Real Estate Market Trends for Williamsburg, Brooklyn, NY. Accessed April 24, 2020. https://www.propertyshark.com/mason/market-trends/Williamsburg_Brooklyn_NYC.



[12]

Figure 3: Williamsburg single-family Median list price (2016.3-2019.2) Source: zillow.com

- **Property Damage**

Over the past few decades, strong climate change perils like hurricanes have resulted in billions of dollars of property damage. The cost of damage includes the cost of repairing buildings, business interruption, replacing equipment and renting temporary space. The cost of property damage has placed great financial burdens on property owners and the casualty insurance industry.

Below is a chart that presented estimated property damage and the estimated insured property damage in past major hurricanes.

Table 1: Estimated Property Damage by Typical Perils

Rank	Date	Peril	Location	Estimated Property Damage (in million)	Estimated Insured Cost of Damage (in million)
1	Aug. 1992	Hurricane Andrew	FL, LA	$27,300	$15,500
3	Aug. 2005	Hurricane Katrina	AL, FL, GA, LA, MS, TN	$81,000	$41,100
4	Sep. 2008	Hurricane Ike	AR, IL, IN, KY, LA, MO, OH, PA, TX	$34,800	$12,500
5	Oct. 2012	Hurricane Sandy	CT, DC, DE, MA, MD, ME, NC, NH, NJ, NY, OH, PA, RI, VA, VT, WV	$50,000	$18,750
6	Sep. 2017	Hurricane Maria (3)	PR, USVI	$55,000	$25,000-$30,000
7	Sep. 2017	Hurricane Irma (3)	AL, FL, GA, NC, PR, SC, USVI	$42,500-$65,000	$22,000-$27,000
8	Aug. 2017	Hurricane Harvey (3)	AL, LA, MS, NC, TN, TX	$25,000-$37,000	$18,000-$20,000
9	Oct. 2018	Hurricane Michael (3)	AL, FL, GA, MD, NC, SC, VA	$16,000-$22,000	$8,000-13,000

Source: corelogic, FEMA, Insurance Information Institute

[12]Zillow, Inc. (n.d.). Williamsburg New York NY Home Prices & Home Values. Retrieved April 15, 2020, from https://www.zillow.com/williamsburg-new-york-ny/home-values/

If we look at all of the hurricanes in the U.S. since 1980 and add up the damages for each five-year period, we see that the damage caused by hurricanes has increased rapidly, especially since entering the 21st century. Below is the graph of estimated loss from 1980 and the classification of storm intensity from the least intensity (Category 1 hurricane) to most intensity.

Figure 4: Estimated loss every 5 years. Source: NOAA[13]

From the above graphs, estimated loss by hurricanes every 5 years boomed from $5.8 billion in 1981-1985 to $367.68 billion in 2016-2020, with a compound growth rate exceeding 80% every 5 years.

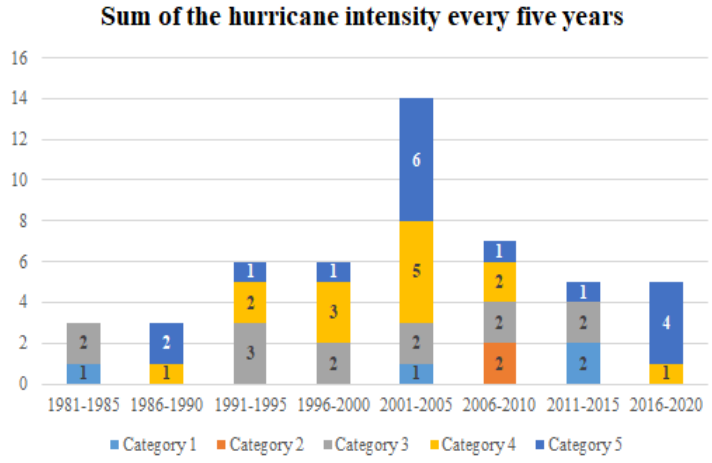


Figure 5: Sum of the hurricane intensity every five years. Source: NOAA[14]

[13] THE DEADLIEST, COSTLIEST, AND MOST INTENSE UNITED STATES TROPICAL CYCLONES FROM 1851 TO 2010 (AND OTHER FREQUENTLY REQUESTED HURRICANE FACTS). (n.d.). Retrieved April 21, 2020, from https://www.nhc.noaa.gov/pdf/nws-nhc-6.pdf

[14] 2010-2019: A landmark decade of U.S. billion-dollar weather and climate disasters: NOAA Climate.gov. (2020, January 8). Retrieved April 20, 2020, from https://www.climate.gov/news-features/blogs/beyond-data/2010-2019-landmark-decade-us-billion-dollar-weather-and-climate

If you look at the sum of different hurricane intensity every five years, in addition to the hurricanes that occurred up to 14 times in 2001-2005, the average number of major hurricanes occurred every 5 years in the past 30 years is about 5 to 7 times. However, four of the five hurricanes that occurred between 2016 and 2020 were the most severe, causing disasters exceeding $370 billion[15] (some losses have not yet been fully calculated), which greatly exceeds the losses due to 14 major hurricanes in 2005 (six of which were category 5 hurricanes). Although the number of major hurricanes that have occurred in most years has remained relatively stable, the losses and damage caused by each hurricane are increasing, and the impact on society is also greater.

From our interview with New York-based real estate developer number 1, we learned that one of their buildings in Manhattan downtown incurred huge damage from Hurricane Sandy in 2012. The basement floor was flooded, and the boilers, fire alarms, electrical equipment, pumps, and other critical equipment were damaged. Half of the building lost its power. Fortunately, the insurance company covered that loss and the building was recovered in a week, but many companies inside the building suffered from the week of suspension and a potential economic loss.

Section 3: Investors and Developers' Responses

Investors and developers interviewed are using different climate risk prediction tools and assessing climate-related financial risks in different ways. Based on this analysis, firms are taking action to protect valuable assets. The real estate industry is also working with government, research institutes, and non-governmental organizations to develop collaborative solutions.

Climate Risk Predictions & Forecasting

As climate risks are getting more frequent and severe, it is crucial to be able to predict and forecast potential climate risk to manage, mitigate and prevent damages to the real estate industry. A climate risk prediction is a probabilistic statement about future climate conditions on different temporal (months to years) and spatial (global, regional or local) scales. It is based on conditions that are known at present and scientific understanding about the physical and dynamic processes that will determine future changes. Climate risk prediction is used for long-term decision making, planning, early warning of potential hazards, and adaptation to climate variability and change. For example, a real estate investor might evaluate climate risks of some specific coastal locations before making investment decisions.

Given the level of expertise and technology that is required to make better predictions and forecasts, and to measure risk exposure, many real estate investors and developers view it as a daunting, difficult, and expensive task if they were to do it themselves. Therefore, just like many others in the industry who still want to factor potential climate risks into their business activities, most of our interviewees are relying on forecasts and predictions provided by external parties such as FEMA, insurance companies, and consulting firms. Only two respondents (European Pension Fund and

[15] Costliest U.S. tropical cyclones. (2018, January 16). Retrieved April 20, 2020, from https://www.nhc.noaa.gov/news/UpdatedCostliest.pdf

Global Logistics) have a proprietary in-house climate risk modelling system to make more customized predictions for their portfolios and assets.

The chart below is an overview and comparison of major Climate Risk Prediction & Forecasting Providers. Each respondent referred to at least one of the listed sources when considering climate change risk. We categorized these information providers by the type of tools they used.

Table 2: Major Climate Risks Prediction Providers.

	Scientific Institution				**Local government**	**FEMA**	**Insurance Companies**	**Consulting firms**
	IPCC	**Earth Institute**	**Digital Coast (NOAA)**	**First street Foundation**				
Role	Climate change prediction provider	Climate change prediction provider	1. Hazard map provider 2. Raw data provider	Flood risk assessment tool provider	Hazard map provider	Hazard map provider	1. Hazard map provider 2. Actuarial (historical based) risk projection providers.	Climate change risk analysis and projection provider.
Free or for-profit	Free	Free	Free	Free	Free	Free	For-profit	For-profit
Type of client (company)	Delta-terra Capital (Consulting firms)	Swiss Re (Reinsurance company) Alliance Bernstein L.P. (Investors)	Jupiter (Consulting firms)	Investors, developers and consulting firms	New York based real estate developer 2 (Investors/ Developers).	New York based real estate developer 2 New York based real estate developer 3 (Investors/develop ers)	Global Logistics Asian Sovereign wealth fund (Investors/develop ers)	Asian Sovereign wealth fund New York based real estate developer 1 (Investors/devel opers)
How to access	Consulting firms use IPCC climate change predictions		1. Consulting firms use the raw data provided by Digital Coast 2. Visualization and predictive tools can be used by the public	Public flood risk assessment tools	Investors/dev elopers use local government hazard maps.	Investors/develope rs use FEMA hazard maps.	Investors/develope rs use insurance companies' hazard maps.	Investors/develo pers use consulting firms' data product that provides granular projections of the impacts of climate change on REITS.
Key Features or tools for climate change risk prediction	The Coupled Model Intercomparin g Project Phase 5 (CMIP5)	co-develop a new curriculum, Climate Science and Portfolio Risk with Alliance Bernstein L.P.	1. Visualization tools and predictive tools (e.g., Sea Level Rise Viewer and Flood Exposure Mapper) 2. Climate change raw data	Flood Factor, FloodiQ	Local original flood risk maps (e.g. NYC Flood Hazard Mapper)	FEMA flood map provided by the National Flood Insurance Program (NFIP).	1. Use catastrophe models (project future potential losses and cost of catastrophes for a specified geographic area.) 2. Some provide their own flood risks map and risk assessment tools to their clients.	1. Most precise climate change risk model 2. Customized climate risks predictions produced by scientific institutes 3.Translate scientific research into business and financial decision-making processes.

Three Most Commonly Used Sources

- **FEMA**

The FEMA flood map is an official public flood hazard information produced by the National Flood Insurance Program (NFIP). The NFIP is a federally backed flood insurance program created by Congress in 1968 and managed by the Federal Emergency Management Agency (FEMA).[16] It targets mostly residential and small businesses because of its limited coverage. For businesses, the program covers up to $500,000 for building property and $500,000 for contents. There is no coverage for business interruption (loss of income following a disaster).[17]

However, some real estate developers and investors among our interviewees say that they check the FEMA flood map to know the flood risk of their properties. FEMA has mapped flood hazards for over 20,000 communities and shows the high-risk areas (1% or greater annual chance of flooding) and moderate-to-low-risk areas (less than 1% annual chance of flooding).

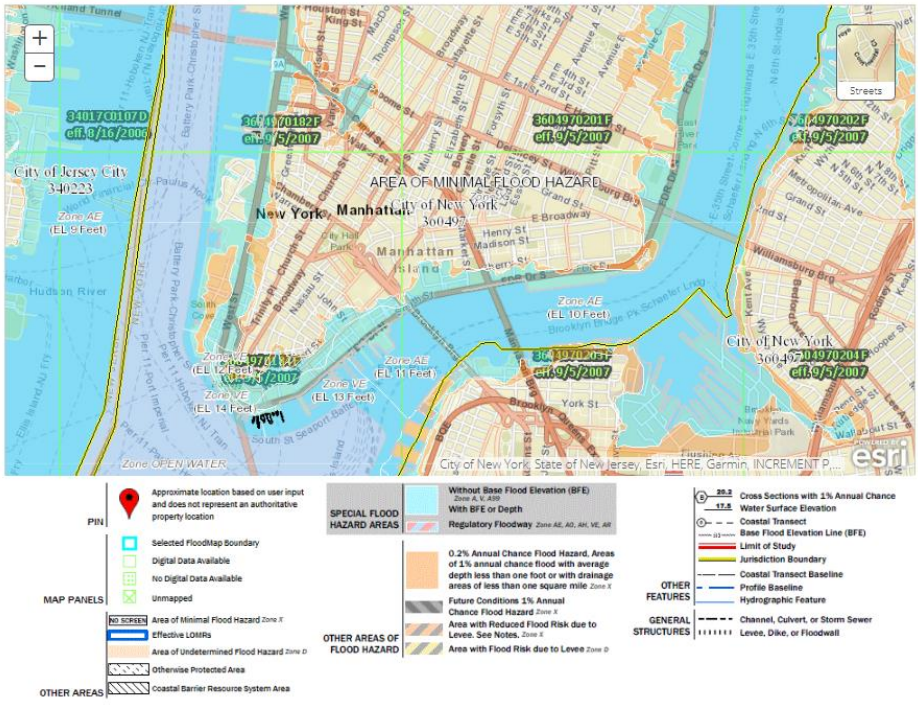


Figure 6: FEMA flood map in NYC Source: FEMA

Nevertheless, the FEMA flood map is often criticized as inaccurate or underestimating risk. According to the Department of Homeland Security, Office of Inspector General report (2017), more than half of flood maps were not updated and valid.[18] Bloomberg (2017) revealed that

[16] Congressional Research Service. (2019, December 23). Introduction to the National Flood Insurance Program (NFIP). https://fas.org/sgp/crs/homesec/R44593.pdf
[17] Congressional Research Service. (2019, December 23). Introduction to the National Flood Insurance Program (NFIP). https://fas.org/sgp/crs/homesec/R44593.pdf
[18] DHS Office of the Inspector General. (2017, September 29). DHS OIG Audit Finds That FEMA's Management of Its Flood Mapping Programs Is Inadequate. https://www.oig.dhs.gov/news/press-releases/2017/09292017/dhs-oig-audit-finds-femas-management-its-flood-mapping-programs

almost two-thirds of those maps were updated more than five years earlier, and some had not changed for over 40 years.[19] Moreover, the flood map does not take into account the effect of climate change but still leverages historical trends[20]. As of September 2018, FEMA's debt to the US Treasury reached $20.5 billion despite Congress canceling $16 billion in 2017.[21] (In 2017, the NFIP earned about $3.6 billion in premium revenue and paid out $8.7 billion.[22]) Although 2017 was the first time that NFIP debt was canceled, Congress appropriated funds between 1980 and 1985 for the NFIP to pay its debt.[23]

- **Insurance**

  Private insurance companies started to enter the flood insurance market in 2013 when the Biggert-Waters Flood Insurance Reform Act of 2012 came into effect.[24] Private insurance companies provide (1) flood insurance that has excess insurance coverage in addition to the coverage provided by the NFIP or (2) their original private flood insurance coverage.[25] They also provide business interruption coverage.[26] Currently, some private insurance companies provide their original flood maps and risk assessment tools to their clients, and some of our interviewees refer to that information to assess the flood risk of their properties.

Table 3: Top 4 Flood insurance provider

	FM Global	Assurant Inc	Zurich Insurance Group	AIG
Direct written premium[27]	$299,749,000	$83,042,000	$77,128,000	$59,759,000
Market shares	42.7%	11.8%	11.0%	8.5%
Type of flood risk info provided	1. The Natural Hazard Maps, which shows the risk of the flood (worldwide), earthquake (China only), hail (the US only).	Several tools for its clients to learn about flood risks and costs created by its in-house flood experts[29]	User-friendly online tool to allow people to detect risks to property	1. Internal U.S. hurricane model 2 Use internally developed flood models to generate flood maps that can be customized

[19] Keller, M., Rojanasakul, M., Ingold, D., Flavelle, C., & Harris, B. (2017, October 6). Outdated and Unreliable: FEMA's Faulty Flood Maps Put Homeowners at Risk. Bloomberg. https://www.bloomberg.com/graphics/2017-fema-faulty-flood-maps/

[20] Scata, J. (2017, October 12). FEMA's Outdated and Backward-Looking Flood Maps. NRDC. https://www.nrdc.org/experts/joel-scata/femas-outdated-and-backward-looking-flood-maps

[21] Congressional Research Service. (2019, December 23). Introduction to the National Flood Insurance Program (NFIP). https://fas.org/sgp/crs/homesec/R44593.pdf

[22] Board, E. (2019, March 30). Opinion | Flood Insurance Reform Won't Be Pleasant. But It's Necessary. Washington Post. https://www.washingtonpost.com/opinions/flood-insurance-reform-wont-be-pleasant-but-its-necessary/2019/03/30/8f07f198-4a72-11e9-93d0-64dbcf38ba41_story.html

[23] Congressional Research Service. (2019, December 23). Introduction to the National Flood Insurance Program (NFIP). https://fas.org/sgp/crs/homesec/R44593.pdf

[24] Better Flood Insurance. Residential & Commercial Coverage Private Flood Insurance. https://www.betterflood.com/private-flood-insurance/

[25] Marlowe, E. (2018, December 20). Flood Insurance for Commercial Properties. Merlin Law Group. https://www.propertyinsurancecoveragelaw.com/2018/12/articles/commercial-insurance-claims/flood-insurance-for-commercial-properties/

[26] Marlowe, E. (2018, December 20). Flood Insurance for Commercial Properties. Merlin Law Group. https://www.propertyinsurancecoveragelaw.com/2018/12/articles/commercial-insurance-claims/flood-insurance-for-commercial-properties/

[27] Grones, G. (2020, January 24). Top 10 flood insurance companies in the US. Retrieved May 7, 2020, from https://www.insurancebusinessmag.com/us/news/catastrophe/top-10-flood-insurance-companies-in-the-us-211413.aspx

[29] Mills, H. (2017, December 11). Best Flood Insurance Companies. Retrieved May 7, 2020, from https://www.consumeraffairs.com/insurance/flood-insurance/#assurant-flood-solutions

	2. Various resources (white papers, articles, videos, and checklists) concerning earthquakes, flood, windstorms, and other severe weather[28]		from floods, landslides, mud and rock slides.[30]	to incorporate climate change views for underwriting and pricing flood risk.[31]

Since insurance and reinsurance companies are the parties that insure climate risks and suffer significantly during climate events, they play a pivotal role in assessing and hedging flood risk. Some of our respondents have effectively outsourced the evaluation and pricing of flood risk to their insurers. Due to the short-term nature of insurance plans (they are usually renewed annually), insurance companies themselves are not obligated to consider long-term climate risks. Instead, they make short-term predictions based on their actuarial models, leveraging historical trends. However, the companies' risk models have not kept pace with the changing level of storm-related risk. Damage claims on climate change-related disasters have been an anomaly in recent years.

From interviews, we found that insurance and reinsurance companies typically rely on catastrophe models, which use historical trends, past scientific and financial data, and past climate disasters information to project future potential losses and cost of catastrophes for a specified geographic area. The models use these vast databases of information to simulate the physical characteristics of thousands of potential catastrophes and project their effects on commercial properties.

The catastrophe modeling process for commercial property includes four key steps:

Step 1. Event generation: A computer run model pulls from a database representing the full spectrum of likely events that can impact the insured's exposed properties. Each event is described by physical characteristics of properties, location, and frequency of occurrence, and the model calculates the likelihood and severity of an event at various properties and insured locations.

Step 2. Hazard: The model determines the event intensity at each insured property for every simulated event that is likely to cause a loss at that location. It examines important site characteristics, including soil condition, distance from the coastline, and elevation to determine ground motion, peak wind gust, and other location-specific conditions.

Step 3. Vulnerability: The model calculates the mean damage ratio and coefficient of variation to buildings and their contents, as well as the resulting loss of use of the building (i.e. business interruption).

[28] NatHaz Toolkit and Maps. (n.d.). Retrieved May 7, 2020, from https://www.fmglobal.com/research-and-resources/nathaz-toolkit

[30] Insurance products and services for those who truly love. (n.d.). Retrieved May 7, 2020, from https://www.zurich.com/products-and-services

[31] Individuals & Families - Insurance from AIG in the U.S. (n.d.). Retrieved May 7, 2020, from https://www.aig.com/

Step 4. Financial model: This model calculates losses to different financial participants, including the insured, insurers, and reinsurers.[32]

Insurers use catastrophe models to determine their probable maximum loss (PML) for various return periods. This allows them to calculate an average annual loss (AAL), which indicates the minimum annual premium that the insurer would need to collect over that return period to cover its expected loss. This ultimately informs insurers' decisions about how to manage risk aggregations, deploy capital, and price insurance.[33]

Catastrophe modeling has grown more sophisticated since it was first implemented in the insurance industry four decades ago. However, catastrophe models still need constant updating based on experience and past events. Even an up to date model can miscalculate the potential damage from a storm or a flood that behaves in an unforeseen manner, potentially by a significant margin.
Underwriters learned a lesson when Hurricane Katrina struck in 2005. The massive storm cost insurers more than $41 billion, mostly in New Orleans. Hurricane models severely underestimated the loss potential, with initial damage estimates identifying only about one-fourth of that total.[34]

Table 4: Most costly hurricanes in US history

Date	Hurricane	Dollars with occurred (in billions)	In 2014 dollars
Aug 2015	KATRINA	$41.1	$48.4
Aug 1992	ANDREW	$15.5	$23.8
Oct 2012	SANDY	$18.8	$19.3
Sept 2008	IKE	$12.5	$13.6
Oct 2005	WILMA	$10.3	$12.1
Aug 2004	CHARLEY	$7.5	$9.1
Sept 2004	IVAN	$7.1	$8.6
Sept 1989	HUGO	$4.2	$7.1
Sept 2005	RITA	$5.6	$6.6
Sept 2004	FRANCES	$4.6	$5.6

Source: Insurance information Institute

A major reason why the initial estimates of Katrina's damage were so far away from the actual damage was that insureds and insurers were feeding bad information of their properties into their models, which included geocoding, occupancy, construction type, years of construction and number of stories. Therefore, beyond specific changes and corrected assumptions built into today's catastrophe models, the biggest lesson from Katrina and other major storms is that models are only as useful as the data that go into them.
According to research from Oliver Wyman, insurer or insured inputted data quality can be improved through a five-step process.

[32]From Katrina to Sandy, Catastrophe Models Adapt to New Conditions. Accessed April 24, 2020. https://www.marsh.com/us/insights/research/advances-in-cat-modeling.html.
[33] Patricia, Klein, & W., R. (2016, May 23). Catastrophe Risk and the Regulation of Property Insurance Markets. Retrieved April 18, 2020, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2782834
[34]Catastrophe Modeling: Why All the Fuss? (n.d.). Retrieved April 20, 2020, from https://www.marsh.com/us/insights/research/catastrophe-modeling.html

Step 1: Natural Hazard Data Management: Insurance companies need to review the insured real estate companies' statement of values to ensure the accurate transposition of changed values.

Step 2: Pre-Modeling Assessment: Insurance and reinsurance companies should perform an initial modeling run to generate AAL results by location. This can help to distinguish any deficiencies in primary data and determine the secondary attributes that can help to resolve quantified risk.

Step 3: Insurance companies' data verification tools can help assess the quality of existing data, including any items that may be inaccurate or incomplete. These tools can also help identify questionable data.

Step 4: Engineering Review: This baseline data should next be reviewed by outside engineering specialists. Using engineering reports provided by the property owner, online tools, and other means — and without making undue assumptions about specific properties — these experts can begin to verify and validate existing data and fill in many gaps.

Step 5: Secondary Assessment: Insurance companies need to re-run the updated data set in their verification tools, which should be able to provide a data quality score. Generally, insurance companies should look to achieve a score of at least 90% complete/accurate data. At that threshold, a risk manager can generally be confident that modeling results provide a reasonable basis for property risk management decisions.

- **Consulting Firms**

  Consulting firms are for-profit entities who are not only able to conduct more customized climate risks predictions for their clients, but also translate, interpret, and incorporate research produced by scientific institutes into business actions and the financial decision-making processes. For example, Four Twenty-Seven[35] has developed a comprehensive framework for evaluating physical climate risk associated with loan portfolios. They calculate detailed projections of exposure to floods from extreme precipitation, hurricane-force winds, sea level rise, water stress and heat stress for each issuer in loan portfolios to reflect the climate risk associated with counterparties, including corporates, projects, sovereigns, financial institutions and local governments. Although consulting firms connect both data providers and end-users, their services come at a cost that not all developers and investors are willing to bear. Some of the respondents would prefer to use public or free sources.

Climate-related Financial Risk Assessment

Besides predicting climate-related risks, developers and investors will also assess the financial implications of those risks to further manage them. Risk assessments can be helpful both during early-

[35] Ambrosio, N. (2020, April 16). Utilities Exposed to Increasing Climate Risk. Retrieved April 18, 2020, from http://427mt.com/2020/01/16/utilities-exposed-to-increasing-climate-risk/

stage planning, and during intermediate and final decision-making activities. They can inform decisions about where to direct investment appropriately and cost-effectively by identifying those areas that are most and least exposed to a variety of climate change risks. Although developers and investors have long used risk assessments to assess their portfolios, in recent years, the objectives of climate adaptation have increasingly been incorporated into the assessment process. Based on research and interview results, there are three common tools that are either currently being used or are recommended for measuring and assessing risk:

- **Risk Assessment for Existing Buildings and Portfolios**

  All the interviewed developers will conduct or have already conducted a risk assessment for existing buildings and portfolios. The assessment process usually includes a thorough onsite examination of the mechanical services and equipment in the building, as well as on-site investigation of portfolios, which ensure risk is mitigated against and opportunities realized early in the asset management process. Some investors also review the extent of tenants' commitment to improve overall climate resilience, especially after catastrophic climate disasters such as hurricane Sandy.

  In our opinion, the vast majority of investors and developers have begun to take the risk of climate change into account as a part of their business operations, especially the companies that have suffered relatively large losses in huge disasters such as hurricane Sandy. However, some companies that do not have losses in the past flooding or hurricanes pay more attention to environmental issues such as waste recycling and energy conservation, and they have not done enough on the adaptation side of climate risk. Although most of the companies are at the very beginning of incorporating climate change risk into their decision making, the increased loss from climate change forces them to think about it and we believe climate risk will gradually become a more important consideration in the future.

- **Due Diligence for New Investments or Acquisitions**

  Due diligence is the most widely adopted aspect of the risk assessment process among respondents. They believe that a complete view of all relevant risks and opportunities is critical in order to identify, avoid, mitigate, and manage risk exposure, as well as to generate improvements which will unlock value in property or investments. According to our interviews, all investors have already considered conducting due diligence before investing, collaborating or building new assets and investments. Although most of the due diligence assessment criteria are proprietary and confidential to our respondents, research shows that some of the other investors are referring to certain indices provided by consulting firms to manage the risk of climate change. For example,

  - Incorporating a climate change risk index which rates climate change vulnerability over the next 20 years for assets in certain regions;
  - Including a “catastrophe score” into its due diligence checklist, which considers risks associated with climate disasters such as flooding and hurricanes

- Incorporating transparency indices such as Jones Lang Lasalle's Real Estate Transparency Index[36]

- **Scenario Analysis**

Scenario analysis evaluates a range of hypothetical outcomes by considering a variety of alternative plausible future states (scenarios) under a given set of assumptions and constraints. In the case of climate change, climate-related scenarios allow an organization to explore and develop an understanding of how the physical and transitional risks and opportunities of climate change might plausibly impact the business over time. However, the use of scenario analysis for assessing climate-related risks and opportunities and their potential business implications is relatively recent. Although our respondents are very familiar with scenario analysis and use it all the time, it is currently rarely used to evaluate the risk related to climate change by investors and developers that we have interviewed (only one consulting firm practiced scenario analysis). To address the lack of expertise and ability to use and interpret big data needed for alternative scenarios, cooperation with consulting firms is a realistic way for investors and developers to do the analysis moving forward.

Indeed, it is a very useful tool to explore climate risk because of the uncertainty of climate change. There is no doubt about the upward trend of both global temperature and sea-level rise, but the magnitude and extent of this upward trend differs among various prediction models. Scenario analysis could establish a range by combining most of the predictions to give the companies a more intuitive and comprehensive result. It can be a bridge to link climate risk with the financial impact of companies.

By referring to the methods and templates provided by the consulting firms and reporting companies, we can summarize four common steps for investors and developers to construct a scenario analysis incorporating the climate risk.

Step 1: Identify the climate-related risks

According to the scenario-based approach developed by TCFD[37], companies should identify the materiality of climate-related risks in their assets at the beginning. The first step is to identify the broad risk from governance, strategy and risk management to make sure the governance is in place, and the process of risk management is appropriate and will incorporate climate risk in their strategy and financial planning. Then, explore the risk at a granular level to check the characteristics of every asset, such as location, maturity, and current status.

[36] Chris.harris, & Chris.harris. (2019, July 29). Climate Risk and Real Estate Investment Decision-Making. Retrieved April 15, 2020, from https://europe.uli.org/climate-risk-and-real-estate-investment-decision-making/

[37] Technical Supplement: The Use of Scenario Analysis in Disclosure of Climate-related Risks and Opportunities (June 2017). (n.d.). Retrieved April 15, 2020, from https://www.fsb-tcfd.org/publications/final-technical-supplement/

Step 2: Set scenarios based on the different terms and locations

After the self-check, companies need to set up different scenarios based on the location of their assets and the number of years they will be held. In terms of location, the company can focus on New York, Miami, Houston, and San Francisco and other coastal cities, and ignore the risks of some inland cities. As for years, it usually sets 5, 20, 30, 50 and 100 years based on short-term, medium-term and long-term predictions. For example, suppose that most of the real estate of a company is located in Miami and has been held for 20 years. Under this condition, a new scenario can be set up.

Step 3: Set sub-scenario in a given year and location

In the scenario of a given time and place, the predicted height of sea-level rise and the severity of possible disasters are two criteria to construct a sub-scenario. Below is an example from 427[38]:

Table 5: Sub-scenario table in a given year and location

Sea Level Rise (SLR) Scenario (2020-2050)	**+SLR (m)**	**Local Storm Surge (+Tides, Waves)**			
		a	b	c	d
		1-yr	5-yr	50-yr	100-yr
[1] Existing conditions	0	0.4 m	0.6 m	0.9 m	1.1 m
[2] 50th percentile	0.08	0.4 m	0.6 m	< 1m	< 1.2 m
[3] 99th percentile	0.20	0.5 m	0.8 m	1 m	1.2 m

From the table above, existing conditions mean there is no rise in sea level and sea level keeps its present level, while the 99th percentile is the worst case among the prediction models. In the column, the severity of disasters is usually expressed in terms of how many years it occurs. Using the sub-scenario, we can see how the different sea levels rise in the next 30 years under different predictions in Alameda, an island city in the San Francisco Bay. For example, if we pick the 50th percentile and column b as the result in the year 2050, it will show that the sea level rise would increase 0.68m combined with the normal SLR (0.08m) and the 5-yr local storm surge (0.6). In that case, a company that has assets in this area with barriers less than 0.68m, compared with the present SLR, would try to find ways to hedge, such as redesigning their buildings or simply selling their assets.

Step 4: Evaluate business impacts and identify potential responses

Based on the different scenarios of sea-level rise, we would expect companies to evaluate the potential impacts on their assets from the asset side and liability side. Each side could be divided into physical risk and transition risk.[39]

[38]Ambrosio, N. (2019, December 5). Demystifying Climate Scenario Analysis for Financial Stakeholders. Retrieved April 20, 2020, from http://427mt.com/2019/12/04/climate-scenario-analysis-for-financial-stakeholders/

[39]Ambrosio, N. (2019, December 5). Demystifying Climate Scenario Analysis for Financial Stakeholders. Retrieved April 20, 2020, from http://427mt.com/2019/12/04/climate-scenario-analysis-for-financial-stakeholders/

Physical risk: the risks associated with the physical effects of climate change. They include changes in water availability, sourcing, and quality; food security; and extreme temperature changes affecting organizations' premises, operations, and employee safety. They may also include legislative and other risks that stem from these hazards, like changes in land-use rules that arise from flooding or storms.

Transition risk: the financial risk that can result from the process of the financial system adjusting towards a lower-carbon economy, including policy, consumer behavior or technological shifts

Table 6: Classification of Climate change risk

	Asset	**Liability**
Physical risk	The direct damage of buildings, equipment, and infrastructure Increase in maintenance and replacement costs Increased instances of business interruption with utility cost	Increase in insurance cost which includes both property insurance and life insurance of employees and also with other disaster relief costs Increased costs from mortgage and debts interest rates related to the direct climate risk.
Transition risk	The price or rent of the house goes down. Increase in technology cost	Increase in potential fines and penalties costs attributed to any legislation change Increase in retrofit cost. Increased costs from mortgage and debts interest rate related to the potential concerns about climate risk.

In the final part of the scenario analysis, companies try to develop an adaptation plan including changing insurance policies (meaning even higher premiums) and implementing retrofits to enhance resilience and to prevent loss based on the risk assessment in the previous steps.

Implications of Risk Prediction and Risk Assessment

Upon knowing potential climate risks associated with certain regions and assessing their respective exposures, developers and investors will then try to prevent potential losses and damages caused by climate risks by incorporating some of the previously mentioned assessment results into their operations and decision-making processes. From interviews, we understand that developers and real estate investors would consider either taking physical adaptation measures, making financial adjustments or a combination of both to mitigate those risks.

- **Structural and Physical Adaptation Measures**

From both interviews and research, it is found that initially most of the structural and physical adaptation measures are adopted for affected assets only after a climate disaster has taken place. However, with increasing awareness of climate risks and better risk predictions and assessments, investors and developers are also adapting to an uncertain future by implementing property resilience measures in anticipation of future climate risks that have not yet occurred broadly, especially at locations where disasters are more prone to occur based on historical data. Some of the measures include:

- **Temporary Flood Barriers for Their Properties**

Half of the developers interviewed whose properties were damaged after Hurricane Sandy built flood barriers immediately after the disaster. Since then, some of them have been proactive in increasing climate change resilience across all their properties to prevent future losses. For existing buildings, developers install temporary exterior barriers to prevent flood water from touching the building envelope. When a new building is located in a flood zone, they anchor temporary flood walls and venting systems inside building lobbies to accommodate storm surges and floods and their associated water pressure build-up without damaging the building.

- **Relocation of Key Equipment to Rooftop**

Although the motivation for undertaking this relocation measure is mixed - some are driven by stricter building codes while others are voluntarily adopting it to prevent future risks and losses - this measure seems to be a relatively common, and yet not as-simple-as-it-sounds measure as compared to others. By placing all critical mechanical equipment and electrical switchgear above grade, developers intend to avoid flood damage to its assets. However, by relocating equipment, half of the developers interviewed also have to redesign the whole system of the buildings (e.g., pumps, fans direction). Relocating equipment also takes up valuable space that could otherwise be leased. Therefore, this measure might be expensive to execute depending on different building designs and structures.

- **Install More Back-up Generators**

Developers install backup generators to support, at minimum, fire and life safety systems, as well as critical infrastructure. For example, Developer 2 has their elevators, lighting, and HVAC systems connected to the backup generator to ensure safe and secure evacuation in the event of an outrage. According to our respondents, this measure is usually carried out in both existing and new buildings without too many technical difficulties.

Broadly speaking, interview results show that developers who have suffered losses from past climate disasters tend to be more proactive in investing in direct adaptation measures for new buildings and the retrofit of existing buildings to prevent future losses. Developers who had no losses in the past are currently thinking about these physical adaptation measures but are less motivated to do so.

Besides these direct adaptation efforts, our respondents are also reviewing the implications on the financial side. The most common action taken by interviewees is getting properties insured. It seems that insurance plays a pivotal role in hedging against flooding risk. Apart from that, some investors would adjust their investment whether by diversifying their portfolios or increasing discount rates to prevent investment in high-risk regions.

- **Financial Implications**

  - **Getting properties insured**

    Most of the developers interviewed chose to insure or have already insured their properties against future climate risks. In general, all of our respondents based their insurance buying decisions on these three factors - contract terms, coverage, and rates. Usually, climate-related insurance, such as flood insurance could be bought either separately for certain assets or as part of a more comprehensive insurance policy. It seems like global real estate investors tend to buy comprehensive insurance policies that cover the entire portfolio, while developers choose to insure climate risks for individual properties, usually those that are located in high risk areas.

  - **Adjusting investment portfolio**

    Besides getting their properties insured, meanwhile, investors and developers are also adjusting their investment portfolio to incorporate climate risk elements in their own financial decision-making processes. In deciding whether new investments or acquisitions should be made in regions with high climate risks such as coastal areas and floodplains, generally speaking our respondents are being cautious to varying degrees.

    On the extreme end, out of nine developers and investors interviewed, only one (Developer 3) chose to halt investment activities completely, and one (Developer 2) does not let geography-specific climate risks impact their decision making in light of considerable property value and appreciation potential, whereas others choose to continue but with stricter due diligence processes, necessary physical adaptation measures, or financial adjustments to price and mitigate those risks.

    A majority of our respondents will price climate risks with proprietary methods and models, such as adjusting discount rates, diversifying portfolios, doing cost-benefit analyses to factor in the cost of potential structural adaptation measures, and additional flood insurance costs into their financial models when calculating expected return of each property investment.

Although it seems like respondents are not completely ignorant of climate risks, they have not made major changes to the way they conduct business in anticipation of the effects of climate change. This is partly because they are not paying for damages and losses, and also because insurance costs are very affordable for all of our respondents. Therefore, unless the cost of insurance becomes high enough in the future to justify changes, developers and investors would be unlikely to react more proactively and aggressively to make changes more significant than those they have already made.

Collaboration

When adapting to climate changes, sometimes investors and developers decide to consolidate expertise to complement their own understanding, assessment, and management of climate risks. Although only one of our respondents (a Miami-based real estate developer) is currently collaborating with other industry players at the moment, research from Miami and NYC shows that more collaborations are happening on the ground. Some developers have contributed funds or ideas to the adaptation strategy research conducted by the government and other parties like NGOs and research institutes. However, overall, collaboration between investors and other parties are more on the exchange of ideas and communication level and lack follow through. Not much in-depth and long-term collaboration has been in place and not many concrete actions have resulted from such collaborations according to both our interviews and research.

- **Collaboration with the Government**

  Hurricane Andrew and Hurricane Sandy were two wake-up calls for developers in Miami and New York to start paying more attention to their buildings' vulnerability against climate change-related disasters. Since then, according to our research, some developers collaborated with the government by supporting and engaging in government task forces and government-initiated climate change resilience panels to express their need to prevent future losses and share their insights about the resiliency of properties to other panelists.

  With concerted efforts between the government and the private sector during public discussion and private risk assessment, reports like Downtown Waterfront, Miami, Florida by Miami Advisory Service Panel and the Progress Report of the Interagency Climate Change Adaptation Task Force of New York City have been published, offering recommendations on building city-wide climate change resiliency. Additionally, the architecture teams of developers together with the government have produced design guidelines of climate resiliency measures including The NYC Climate Resiliency Design Guidelines. Though, overall, the recommendations generated by those reports are generally vague and the concrete actions for future collaboration between private and public sectors listed lack follow through and further implementation.

- **Co-sponsoring Government-initiated Panels and Engaging in Government Task Forces**

  Some developers collaborated with the government by co-sponsoring government-initiated climate resiliency panels. A case study is the Miami Advisory Services panel, where the government and Swire Properties collaborated to co-sponsor this event.

  The Miami Advisory Service panel was initiated by The City of Miami and the Miami Downtown Development Authority who asked the Urban Land Institute to conduct a panel to provide recommendations for addressing waterfront resilience and mitigating the effects of sea level rise along Biscayne Bay and the Miami River. During this 5-day public panel, panelists toured sites along the bayfront and riverfront and interviewed over 80 stakeholders, then they published a report providing recommendations tailored to Downtown Miami.[40] Key recommendations are incremental actions to build city-wide resiliency including recommended adaptation designs, embracing sensitive transit-oriented development (TOD), systemize existing plans and creating a portfolio of financial strategies in resilient investment.

  It is a fruitful event out of public-private collaboration as the recommendations put forward are concrete, region-specific and call for deeper private-public collaboration. As it is a government-sponsored panel supported by the private sector, recommendations proposed by it are more likely to be implemented. Specifically, some tailored recommendations like creating a portfolio in resilient investment and implementing a Living Shoreline Demonstration Project can be very effective in building city-wide climate resilience if successfully implemented through close public-private collaboration. However, as it's a relatively new report, we have not seen any further collaborative actions on those recommendations so far.

  The NYC Panel on Climate change consists of leading private sector practitioners to produce The NYC Climate Resiliency Design Guidelines, helping inform ways to design buildings so that they will be able to withstand the climate change challenges of the future. The NYC Panel on Climate change has been helping New York City prepare for climate change since 2008. NPCC developed a tool called the Antarctic Rapid Ice Melt Scenario, which models the effects of melting ice sheets on sea level rise around NYC. It shows that, under a high-end scenario, monthly tidal flooding will begin to affect neighborhoods around Jamaica Bay by the 2050s and many other coastal areas around New York City by the 2080s. Increased engagement and participation in these types of panels by private sector participants can increase awareness of the latest science around climate change adaptation.

  The City of New York developed a "Climate Change Adaptation Task Force" as part of the NYC Mayor's Office of Resiliency bringing experts in this field including developers to participate in the climate risk assessment process. The Climate Change Adaptation Task Force was formed in 2008, and was crucial in New York's response to Hurricane Sandy. The task force was composed of leading climate change and impact scientists, academics, and private sector practitioners. It identified critical infrastructure in New York City that

[40] Urban Land Institute. (2019, June 7). Waterfront Resilience Miami, Florida. Retrieved April 22, 2020 from https://americas.uli.org/wp-content/uploads/sites/2/ULI-Documents/ULI-ASP_Report_Miami_FINAL.pdf.

could be at-risk from the effects of climate change, and developed coordinated adaptation strategies to secure those assets.

Following Hurricane Sandy, The Urban Green Council in New York City convened leaders in the NYC real estate community to participate in The Building Resiliency Task Force. This body was tasked with providing recommendations to improve building resiliency and increase preparedness for future extreme weather events. Recommendations to commercial real estate owners included elevated equipment, sidewalk flood barriers, storing sandbags, having sewage valves that prevent the backflow of sewage into basements during storms, sidewalks sloped into tree pits, and natural gas generators.

- **Collaboration with Research Institutes and NGOs**

According to our interview and online case study research, some developers have collaborated with research institutes and NGOs including ULI, GM&B and Universities to contribute experience, ideas or funds to increase the whole region's climate change resilience. This type of collaboration is more frequently seen in Florida which is more vulnerable to climate change risk than in New York. Amongst the following collaborations, developers' participation in resiliency task forces and the funding of resiliency strategy research are likely to have a greater impact on increasing regional climate resiliency. However, collaboration on co-designing physical adaptation measures between developers and other parties are in very initial stages and may take a long time to translate into meaningful impacts.

- **Co-designing Architectural Measure to Increase Buildings' Climate Resiliency**

One of the main components of developers' adaptation strategies is conducting physical adaptation measures, e.g. building waterproof walls and temporary flooding barriers. In order to find out the most cost-effective physical adaptation measures, some developers have been collaborating with research institutes and universities to design new ones.

A case study from our interview is a Miami-based real estate developer who has been collaborating with Urban Land Institute and the University of Miami on designing architectural measures to build up buildings' resiliency. For example, they are working together to develop an advanced lighting system that will still work even if the building is flooded and landscaping to absorb water.

However, this type of collaboration has not commonly been seen up until now and no significant output on new adaptation designs have been produced. It may take a long time to have a great impact on climate resiliency building of the real estate industry.

- **Funding Resiliency Research Strategy**

Some developers also worked with NGOs by funding their projects on adaptation strategy design. A typical case study of this kind of collaboration is the GM&B-initiated

Resilient305 strategy. GM&B (Greater Miami &Beaches) is a team that brought together communities such as The Miami Foundation, the cities of Miami and Miami Beach and 100 Resilient Cities in the greater Miami area. They worked together to create a regional resiliency strategy plan called Resilient305. In recent years, GM&B has witnessed their funding sources for Resilient305 strategy broadened to include more private partners.

Launched in 2016, Resilient305 Strategy was a living document created to address resilience challenges they prioritized through intergovernmental and community collaboration. A key part of it is how the city can increase its resilience against climate change-related natural disasters. From 2016 to 2019, the Resilient 305 team engaged thousands of stakeholders including developers across the region and asked them about what they felt the region's biggest challenges and opportunities were with regard to resiliency. The additional funding they obtained from the private sector including real estate developers enabled them to conduct a more thorough investigation and they managed to officially launch Resilient305 in 2019. The strategy plan identified 50 recommended actions. Key actions for adapting to climate perils include developing sea level rise checklists for capital projects, reducing "back bay" flooding and stakeholder resilience training.[41]

As this strategy was based on a 3-year investigation and it has received support from both the government, private sector and communities, it is likely to yield a meaningful impact on the Greater Miami area by guiding regional collaborative actions towards more regional-wide resiliency in the long run. However, the advice specifically for building climate resilience is not concrete enough so far. Simply by recommending the checklist and training are more like actions of raising awareness rather than actions that can effectively enhance regional climate resilience. The collaboration we have seen during the drafting of Resilient 305 can serve as a great starting point for broad regional collaboration. However, the recommendations put forward now are vague about how specifically should different parties work closer together to improve regional climate resilience.

Section 4. Trends in the Near Future

Although it is important to understand the current status of climate adaptation efforts by developers and investors to set the stage, relevant stakeholders must also stay alert and get ready for important trends that will greatly shape and impact the future industry landscape, especially given the forward-looking nature of climate risks. This report has identified three broad trends that are relevant to the industry in adapting to climate risks:

[41] GM&B. (2019, May). Resilient 305 Strategy. Retrieved April 22, 2020, from https://resilient305.com/wp-content/uploads/2019/05/Full-Strategy-2.pdf

Technological Development Enhances Risk Prediction and Data Accuracy

During the past few decades, national and international investment in climate observations, research and modelling have resulted in significant progress in experimental and practical climate prediction, as well as significant improvement in scientific understanding of climate variability and change. These improvements have translated directly into advances in detecting and attributing human-induced climate change, simulating past and future climate in models, and understanding the links between the climate system and other environmental systems.

For example, the ability to realistically simulate natural climate variations has been a critical driver for, and test of, the development of climate models[42]. Improved understanding of natural variability modes is also critical for improving regional climate projections, especially on decadal time scales[43].

For specific climate disaster predictions, such as flash floods, the Deep Learning Neural Network (DLNN)[44] algorithm is viewed as a promising new tool for predicting flash floods in prone areas. Meanwhile, integrated forecasting systems and methods such as Finite Element Method (FEM) or Finite Volume Method (FVM) are being improved to enhance our understanding of storm surges to better predict a single storm's occurrence as a result of synergistic climate change effects[45]. For predicting sea level rise, although projections of future sea level rise cannot be validated at the moment, there is a lot of progress being made that laid a solid scientific foundation for better models with enhanced accuracy[46].

With technological advancement, we expect to see better models, tools and products that are capable of producing more precise risk predictions and data that are granular enough to assess the extent to which an asset is resilient in the face of today's climate change realities.

Market Transition

- **More Climate Risk Analysis Firms**

  In the past decade, the industry has witnessed the emergence of numerous firms specialized in analyzing climate change impacts, risk prediction, and forecasting, as well as assisting capital markets in understanding the business implications of those risks. In 2012, Emilie Mazzacurati

[42] Read "Advancing the Science of Climate Change" at NAP.edu. (n.d.). Retrieved from https://www.nap.edu/read/12782/chapter/7#93
[43] Ibid. 34.
[44] Bui, D. T., Hoang, N.-D., Martínez-Álvarez, F., Ngo, P.-T. T., Hoa, P. V., Pham, T. D., … Costache, R. (2019, September 12). A novel deep learning neural network approach for predicting flash flood susceptibility: A case study at a high frequency tropical storm area. Retrieved from https://www.sciencedirect.com/science/article/pii/S0048969719344043
[45] Kohno, N., Dube, S. K., Entel, M., Fakhruddin, S. H. M., Greenslade, D., Leroux, M.-D., … Thuy, N. B. (2019, May 22). Recent Progress in Storm Surge Forecasting. Retrieved from https://www.sciencedirect.com/science/article/pii/S2225603219300207
[46] Researchers Reveal Ways to Better Predict Future Sea Level Rise. (n.d.). Retrieved from https://wws.princeton.edu/news-and-events/news/item/researchers-reveal-ways-better-predict-future-sea-level-rise

founded Four Twenty Seven, a California-based climate risk data firm, after Hurricane Sandy revealed that climate change could damage even the financial institutions.[47] Another renowned California-based climate risk data firm, Jupiter Intelligence, was founded in 2017 and specializes in quantifying physical risk in a changing climate.[4849] Additional climate risk analysis firms that analyze the climate risks on real estate properties include The Climate Service (founded in 2017), Carbon Delta (founded in 2015 and acquired by MSCI in 2019), and DeltaTerra Capital (founded in 2019).[505152] Their services enable clients to assess asset-level to portfolio-level climate risk in financial terms by various locations, time periods, and emissions scenarios. Their clients are enterprises, asset owners, financial institutions, insurance companies, and governments. With increasing market awareness of climate risks and the cruel fact of climate change, we expect the trend to continue in the future where more and more firms will join the market and provide various climate risk assessment services with the real estate industry.
Please see the product description of each firm in Appendix 1.

- **Increasing Free Access to Climate Risks Related Data**

Currently, there are a few publicly available data and tools for concerned stakeholders to learn, understand, and assess climate risks at their own discretion. Some reliable public resources have been released by nonprofit and governmental organizations such as the First Street Foundation (FloodiQ.com) and NOAA-sponsored Digital Coast (e.g., Sea Level Rise Viewer and Coastal Flood Exposure Mapper), as well as local governments (e.g., NYC Flood Hazard Mapper). Moreover, the First Street Foundation will release a free-access asset-level flood risk assessment tool (Flood Factor) in Q2 2020.[53] Flood Factor will cover the entire US with multiple sources of flooding being taken into account (river, rain, surge, tide).[54] Those public resources enable real estate stakeholders to assess the flood risks of properties by various time periods and scenarios. Meanwhile, Oasis Loss Modelling Framework, not-for-profit company founded in 2012 and owned by the insurance industry, provides an open-source catastrophe modeling platform for a better understanding of risk in insurance and beyond.[5556] We expect to see greater climate risk data transparency in the future.
Please see the product description of each organization in Appendix 2.

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[47] Four Twenty Seven. *Our Story.* http://427mt.com/our-story/
[48] Jupiter Intelligence. About [LinkedIn page]. Retrieved May 1, 2020 from https://www.linkedin.com/company/jupiterintel/about/
[49] Jupiter Intelligence. *About*. https://jupiterintel.com/about/
[50] The Climate Service. About [LinkedIn page]. Retrieved May 1, 2020 from https://www.linkedin.com/company/the-climate-service/about/
[51] MSCI. (2019, September 9). MSCI to StrengthenClimate Risk Capability with Acquisition of Carbon Delta [Press release]. Retrieved https://www.msci.com/documents/10199/e884e4bb-dde8-ee6a-6dfc-e38eabaaafd8
[52] Burt, D. Posts [LinkedIn page]. Retrieved May 1, 2020 from https://www.linkedin.com/in/dave-burt/
[53] Sieberg, D. & Porter, J. (2020, March 2). How America's Most Comprehensive Flood-Risk Model Is Assembled. First Street Foundation https://firststreet.org/flood-lab/research/article-comprehensive-model/
[54] First Street Foundation. Flood Factor. https://firststreet.org/flood-factor/
[55] Oasis Loss Modelling Framework Ltd.. About [LinkedIn page]. Retrieved May 1, 2020 from https://www.linkedin.com/company/oasis-loss-modelling-framework-limited/about/
[56] Oasis Loss Modelling Framework. https://oasislmf.org/

- **Climate Risk Innovation in the Insurance Industry**

The insurance industry is one of those that suffers the most from climate change. Currently, some insurers are trying to incorporate future climate risk into their actuarial models. According to Fortune, Swiss Re, the world's largest reinsurer, has collected more than twice as much in premiums as it has spent in payout over the last two decades.[57] However, in 2017 and 2018, the company spent more on a large natural catastrophe than what its internal model anticipated. Swiss Re is confident that this trend is related to rising temperatures. The company is now working with the applied-mathematics and applied physics department of the engineering school of Columbia University to assess the climate change impact on Hurricanes.

Meanwhile, three insurance firms, QBE (Australia's second-largest global insurer), Mitsui MS&AD (Japanese largest non-life insurer), and Nephila (world's largest insurance-linked securities manager), invested in Jupiter Intelligence in 2019.[58][59][60][61] QBE Group Chief Operations Officer David McMillan said that the company would incorporate Jupiter's data analytics to improve underwriting and pricing to provide resiliency management expertise for its customers.[62] The company expects that insurance premiums for its customers in high climate risk areas will become unaffordable in the long term.[63]

FEMA, which administers the National Flood Insurance Program, is also redesigning its risk rating system (Risk Rating 2.0), which will go into effect in October 2021.[64] FEMA has long used the rating methodology created in the 1970s but will introduce a fundamentally new rating system by adopting industry best practices and modern technology. While the current rating system is dependent on the 1-percent-annual-chance-event, Risk Rating 2.0 will incorporate a broader range of flood frequencies.

We expect that insurance premiums will not rise significantly in the short-term because the industry has just begun to work towards incorporating climate risk, and the risk premium is also influenced by other factors such as market competition. However, integrating climate risk to insurer's actuarial model is inevitable to avoid further loss due to climate change, and, in the

[57] Ball, J. (2019, October 24). Climate Change Is Hitting the Insurance Industry Hard. Here's How Swiss Re Is Adapting. Fortune. https://www.chicagomanualofstyle.org/tools_citationguide/citation-guide-1.html

[58] Wood, C. (2019, March 21). MS&AD, QBE and Nephila among Investors of Climate Data Startup Jupiter. Reinsurance News. https://www.reinsurancene.ws/msad-qbe-and-nephila-among-investors-of-climate-data-startup-jupiter/

[59] Job, S. (2020, April 13). Coronavirus Watch – Subscribe Now
Australia's QBE Insurance to raise $825 mln in capital to counter coronavirus pressures. Reuters. https://www.nasdaq.com/articles/australias-qbe-insurance-to-raise-%24825-mln-in-capital-to-counter-coronavirus-pressures

[60] The Toa Reinsurance Company, Limited. (2019). Japan's Insurance Market 2019. https://www.toare.co.jp/english/html/pdf/2019_insurance.pdf

[61] Nephila. Home. https://www.nephila.com/

[62] Wood, C. (2019, March 21). MS&AD, QBE and Nephila among Investors of Climate Data Startup Jupiter. Reinsurance News.

[63] Pandey, S. (2020, February 17). Climate change could make premiums unaffordable: QBE Insurance. Reuters. https://www.reuters.com/article/us-climate-change-qbe-ins-grp-idUSKBN20B0DA

[64] FEMA. (2019, November 15). NFIP Transformation and Risk Rating 2.0. https://www.fema.gov/nfiptransformation.

long-term, these trends will lead to higher insurance premiums or insufficient coverage for high climate risk properties.

- **Deeper Market Integration in Debt Market to Operationalize Climate Risk**

With an increasing emphasis on ESG issues in the past decade, the debt market also begins to focus on climate risks by acquiring expertise in that field to complement their understanding. In July 2019, Moody's Corporation acquired a majority stake of Four Twenty Seven to strengthen the integration of climate-related physical risks into its economic modeling and credit ratings.[65] In November 2019, Trucost, an ESG analysis company acquired by S&P Global in 2016, announced the launch of Climate Change Physical Risk analytics, which provides investors and companies with assessments of the various types of climate risk to their assets.[66] These integrations are clear signs that the debt market is thinking of incorporating climate risks into their business. Once rating agencies incorporate those risks, the cost of borrowing will increase for projects or companies with high climate risk.

- **More Disclosure on Climate Resilience Related Risk Management**

In the past decades, there has been an increasing emphasis and demand for sustainability or Environmental, Social and Governance (ESG) related disclosure from investors, companies, and other stakeholders as a risk management tool[67]. Internationally and locally, as a result, more disclosure standards and frameworks, such as SASB, CDP, and GRI have also been developed to facilitate and standardize both reporting content and processes.

Most recently, in the U.S., in light of more frequent climate risks, shareholder resolutions have been filed asking companies to disclose data on their climate change-related lobbying, to disclose risks to their bottom lines posed by climate change and to disclose risks posed to the climate by their business operations[68]. Investors are also continuing to press companies to disclose how they plan to align their operations with the goals of the Paris Agreement, even against the backdrop of the Securities and Exchange Commission's move to restrict such disclosure[69].

[65] Four Twenty Seven. (2019, July 24). Four Twenty Seven Receives Majority Investment from Moody's Corporation. http://427mt.com/2019/07/24/four-twenty-seven-receives-majority-investment-from-moodys-corporation/
[66] Trucost. (2019, November 26). Trucost Launches Physical Risk Analytics to Help Assess Risks and Opportunities from Climate Change. https://www.trucost.com/trucost-news/trucost-launches-physical-risk-analytics-to-help-assess-risks-and-opportunities-from-climate-change/
[67] Eccles, R. G., & Klimenko, S. 2019, April 26. Shareholders Are Getting Serious About Sustainability. Retrieved from https://hbr.org/2019/05/the-investor-revolution
[68] Shareholders demand more climate disclosure as the SEC tries to restrict them. 2020, January 10. Retrieved from https://www.climateliabilitynews.org/2020/01/10/shareholder-resolutions-sec-climate/
[69] Climate-Related Risk Disclosure Under U.S. Securities Laws. September 10, 2019. Retrieved from https://fas.org/sgp/crs/misc/IF11307.pdf

Table 7: Prevalent Reporting Standards

Standard	Focus	Scoring	Who Reports
CDP	Primarily GHG emissions, but has grown to address water and forestry issues as well.	Companies receive two separate scores for Disclosure and Performing using a 100-point scale. CDP recognizes top scoring companies in the Carbon Disclosure Leadership Index.	Public and private companies, cities, government agencies, NGOs, supply chains.
Dow Jones Sustainability Index	Industry-specific criteria considered material to investors. Equal Balance of economic, social and environmental indicators.	Companies receive a total Sustainability Score between 0-100 and are ranked against peers; those scoring within the top 10% are included in the index.	The 2,500 largest public companies in the world.
GRI	Corporate social responsibility with an equal weight on ESG factors.	Focus is on transparency so no true scoring methodology.	Public and private companies, cities, government agencies, universities, hospitals, NGOs.
SASB	US public companies only. Industry-specific issues deemed material to investors.	No scoring system. SASB is a standardized methodology for reporting sustainable performance through the Form 10-K.	U.S. listed companies.

Such demands and requests have fueled the establishment and formation of more climate-related disclosures, such as the Task Force on Climate-related Financial Disclosures (TCFD), a set of climate-related financial risk disclosures guidelines that are recommended for use by companies in providing information to investors, lenders, insurers, and other stakeholders[70]. The Task Force will consider the physical, liability and transitional risks associated with climate change and what constitutes effective financial disclosures across industries. The work and recommendations of the Task Force will help firms understand what financial markets want from disclosure in order to measure and respond to climate change risks, and encourage firms to align their disclosures with investors' needs.

Zooming out to the real estate sector, GRESB was established in 2009 by a group of large pension funds who wanted to have access to comparable and reliable data on the ESG performance of their investments. In the intervening years, GRESB has grown to become the leading ESG benchmark for real estate and infrastructure investments across the world, and has been adopted by almost all of our respondents. In recent years, according to GRESB, investors are demanding more information on climate resilience beyond traditional ESG metrics, and want to have increased access to information about strategies used by property and infrastructure companies to assess and manage risks from social and environmental shocks and stressors, including the impact of climate change[71]. Responding to such demands, more climate resilience focused risk disclosure systems are created, for example, the GRESB Resilience Module.

[70] Task Force on Climate-related Financial Disclosures: TCFD - About. (n.d.). Retrieved from https://www.fsb-tcfd.org/about/#

[71] "About". GRESB Resilience Module. (n.d.). Retrieved from https://gresb.com/resilience-module/

Unlike other GRESB Assessment or reporting systems, such as the GRESB Infrastructure Fund Assessment, Real Estate Assessment, and Infrastructure Asset Assessment, the Resilience Module does not attempt to assess or communicate specific risks to individual assets. Rather, it provides a framework to report on the processes used to conduct climate risk assessments and the results from these assessments[72].

For the Module, resilience is defined as the ability of an entity (e.g. organization or fund) to plan for, respond to, and rebound from short-term shocks and long-term stressors. The Resilience Module addresses two fundamental categories of climate-related risk identified by the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD): transition risk and physical risk. Participants will be asked to disclose climate resilience associated with four sections, Leadership & Governance, Risk Assessment, Business Strategy & Financial Planning Performance, and Metrics & Targets. Sample questions from the Resilience Module are provided in the Appendix. The overall Module results would be shared voluntarily by participants to promote communication and learning among real estate investors, developers and fund managers to enhance their own risk assessment and management process[73].

These aforementioned developments have shone a spotlight on ESG performance and disclosures specific to climate-change. It is important for boards and audit committees to be aware of the increased focus being placed on climate-change disclosures and determine how best to exercise their oversight role to respond to this focus. At the same time, we expect to see more of such disclosure to emerge in the future.

Government Regulations

In response to past climate change-related disasters, especially sea level rise, hurricanes and flooding, we noticed major changes on the government side with regard to climate resilience over the past decades. Major changes include adding mandatory adaptation measures to the building code, proposing establishment of city-wide adaptation projects and creating new government resilience-focused agencies.

With the projected increasing intensity and frequency of climate perils and the current trends on the government side, we expect to see stricter building code for new buildings on required adaptation measures, making adaptation measures mandatory for existing buildings, more resilience-focused government agencies and more regional-wide projects that may asked developers to shoulder part of the cost in the following decades. The majority of those trends will hand over more of the cost to developers who have properties in areas vulnerable to climate perils and negatively influence their property values. Thus, we expect the trends in government regulations will impact developers' adaptation strategies and even investment strategies in the long run.

[72] Ibid., 56
[73] Ibid., 56

- **Stricter Building Code on Required Adaptation Measures**

Huge losses from hurricanes and flooding during the 1990s in Florida led to a comprehensive review of Florida's building code system. A subset of the building code focusing on hurricanes was created and more adaptation measures were incorporated in the building code, including elevation of building by a whole foot and required setback for waterfront buildings.[74] Also, in New York, after Hurricane Sandy, mandatory adaptation measures including relocation and protection of building systems and critical equipment in flood-prone areas and elevating buildings at least 2 feet above the base flood elevation have been added to its building code. [75]

According to our interviews with developers, many of them said the damage to core equipment in the basement that resulted in the loss of power and heat was problematic and caused huge additional replacement costs. Thus, adaptations like the relocation of core equipment and back-up generators can effectively mitigate their losses from future flooding. Although the core equipment can be protected, other parts of the building may still suffer from significant damage because the current requirements on temporary flood barriers, elevation of buildings and setbacks are inadequate to protect the building from severe storms and tidal flooding. Therefore, to further increase buildings' climate resilience, we expect to see a stricter building code with regard to adaptation in the future in the following three ways.

- **More and Stricter Mandatory Adaptation Measures**

Mandatory adaptation measures fall into two categories. One is the physical measures inside or around the building. Another is the requirement for the building itself, including elevation and setback. For the first category, according to FEMA's analysis, current mandatory adaptation measures are inadequate. For instance, temporary flood barriers can currently provide effective protection to buildings that experience flood levels of 4 feet, but for flash floods that can reach heights of 30 feet or more, barriers may become ineffective.[76] Hence, we expect more effective adaptation measures with stricter requirements will be added in the building code for floodplain buildings.

For the second type of mandatory measure, new studies show that current measures are inadequate to mitigate losses from future climate perils. In Miami, a new study calls for another foot of building elevation in late 2019[77]. According to the 2019 Compact Unified Sea Level Rise Projection published by the Southeast Florida Regional Climate Change Compact, the state can

[74]Florida Department of Business and Professional Regulation. (2017, July). 2017 Florida Building Code -Test Protocols for High Velocity Hurricane Zone, Sixth Edition. International Code Council, Inc. Retrieved April 22, 2020 from https://codes.iccsafe.org/content/FTPC2017

[75]FEMA. (2014, November). Building Science Support and Code Changes Aiding Sandy Recovery---Hurricane Sandy Recovery Fact Sheet No.3. Retrieved April 15, 2020 from https://www.fema.gov/media-library-data/1416428696553-d2b2c680a77990ed9e786b8821f850b0/SandyFS3Recovery_508.pdf

[76]FEMA. *Non-Residential Floodproofing— Requirements and Certification.* Retrieved April 23, 2020 from https://www.fema.gov/media-library-data/20130726-1511-20490-5294/job6.pdf.

[77]Harris, A. (2019, November 12). Florida's building code doesn't take sea rise into account. That could change. *Miami Herald*. https://www.miamiherald.com/news/local/environment/article237241299.html

expect 1.75 to 4.5 inches of sea-level rise by 2070 above 2000 mean sea level[78]. Those extra inches have contributed to a fivefold rise in the frequency of high-tide flooding across the nation.[79]Consequently, it is expected that the government will require higher elevation for new buildings and longer setbacks of waterfront buildings.

This trend may add extra cost to developers who plan to construct new buildings and it may drive investors to invest more in higher elevation areas. And for a booming market for real estate like Miami and New York, a longer setback means smaller developable squares that may limit the acreage of the buildings and value losses to the developers.

- **Requiring Developers to Construct More Resilient Infrastructure around Their Buildings**

Currently, the Miami building code requires developers of waterfront buildings to construct seawalls and high elevation waterfront sideways around their buildings with specific requirements.[80] In New York, there is no similar requirement yet. However, in 2012, many infrastructure including roads and tunnels in NYC were inundated because of Hurricane Sandy which took more than 5 years and more than $10 billion to repair[81]. Because of NYC infrastructure's vulnerability to climate perils and the government's budget limit, we expect NYC to mirror the practice of Miami, requiring waterfront building developers to build climate resilient infrastructures and improve the climate resilience of tunnels and substations near their buildings in the future.

For Miami, there is currently no requirement for improving the climate resilience of existing infrastructure. However, from our interview with a Miami-based real estate developer, we learned that some Miami developers have elevated roads around their buildings on their own voluntarily. With this kind of market trend, we expect that the government will demand developers to be responsible for more construction and improvement work of adaptation infrastructure, e.g. building flood shelters and elevating roads.

However, with this government regulation trend, additional cost of infrastructure will be evaluated in the DCF model of developers that may negatively influence the property value and their investment decision.

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[78]Southeast Florida Regional Climate Change Compact. (2019). *2019 Compact Unified Sea Level Rise Projection.* Retrieved April 22, 2020 from https://southeastfloridaclimatecompact.org/announcements/the-compact-releases-its-3rd-regionally-unified-sea-level-rise-projection/.

[79]Dahl, K. (2020, March 20). Blame Miami Beach's high-tide flooding on sea-level rise and climate change | Opinion. *The Sun Sentinel*. https://www.sun-sentinel.com/opinion/commentary/fl-op-com--20200320-ruxpz3m5rbdlxfox7tsasiomki-story.html

[80]City of Miami Planning and Zoning Department. (2019, January). *Miami 21 Code-Appendix B Waterfront Design Guideline*. Retrieved April 15, 2020 from https://codehub.gridics.com/us/fl/miami#/80117d52-4069-4169-b7c2-9cbdb12944d5.

[81]McGeehan, P., & Hu, W. (2017, October 29) Five Years After Sandy, Are We Better Prepared? *The New York Times*. https://www.nytimes.com/2017/10/29/nyregion/five-years-after-sandy-are-we-better-prepared.html

- **Requiring Mandatory Adaptation Measures for Existing Buildings**

  Currently, requirements on adaptation measures and designs is only mandatory for newly built buildings in the building codes of Florida and New York[82]. Currently, however, the real estate market in Florida is mainly composed of old buildings, and not much land is left for new buildings. Likewise, the majority of the buildings in New York City are old buildings. Only requiring new buildings to increase climate change resiliency is far from enough to increase city-wide resiliency.

  One recommendation from FEMA's Mitigation Assessment Team Report for Hurricane Sandy in New Jersey and New York is that the elevation requirement should also apply to existing buildings that are undergoing repair or retrofit that do not meet Substantial Improvement/Damage criteria. The report also recommends the city should develop guidance on mitigation solutions for existing residential buildings[83].

  Hence, to better improve the state's resistance against natural disasters intensified by climate change and to come better in line with FEMA's recommendation, we are expected to see the requirement of adding new equipment or change some design of the building to improve its climate resiliency be also applied to buildings already constructed. However, if those measures are made mandatory, it will be much more costly for existing buildings than new buildings and may influence developers' investment, as a majority of developers are currently investing in existing buildings in New York City and retrofitting them. If adaptation measures are made mandatory through the repair of existing buildings, the cost will be added into developers' financial model and shaped their value estimation of investments.

- **Creating New Resilience-Focused Government Agencies**

  After Hurricane Andrew, Miami-Dade County established the Office of Resilience in 1996 in order to better prepare for future climate change related risks. The same kinds of actions were seen in New York City following Hurricane Sandy. The City of New York established the NYC Mayor's Office of Recovery and Resiliency in 2014. It leads the city's $20 billion resiliency effort to prepare NYC for the growing impacts of climate change. It helped develop the NYC Flood Hazard Mapper, which shows the current and future flood threats to New York City. It also oversees New York's OneNYC climate resiliency program. OneNYC has identified specific measures that the city can take to defend the city's shorelines, protect the city's infrastructure and make the city better prepared for climate change. The Mayor's Office of Recovery and Resiliency, along with the NYC Economic Development Corporation, is also working on a plan to protect lower Manhattan called the Financial District and Seaport Climate Resilience Master Plan, which will include a comprehensive design for shoreline extension and establish a new public-benefit corporation to finance, construct, and manage it.

[82]New York State Department of State, Division of Building Standards and Codes. (2015, November). *2015 International Existing Building Code (5th printing as adopted by New York State)*. International Code Council, Inc. Retrieved April 22,2020 from https://codes.iccsafe.org/content/IEBC2015NY

[83] FEMA. (2013, November). *Mitigation Assessment Team Report: Hurricane Sandy in New Jersey and New York*. Retrieved April 15, 2020 from https://www.fema.gov/media-library-data/1386850803857-025eb299df32c6782fdcbb6f69b35b13/Combined_Sandy_MAT_Report_508post.pdf

At the state level, the New York State Governor's Office of Storm Recovery was established in June 2013 as a response to Hurricane Sandy. The Office of Storm Recovery is involved in shoreline resiliency projects, drainage improvement projects, and is also developing a resiliency trades certification program focused on skills that are critical to retrofitting homes and buildings for flood hazard mitigation.

In the future, because of the projected increasing frequency and intensity of hurricanes, we expect to see additional offices being added to resilience-focused government agencies and the creation of more resilience-focused government agencies responsible for different fields.

- **Building Barriers to Prevent Damage to Shoreline**

To protect Manhattan's highly valuable and vulnerable assets, there have been plans to build a six-mile sea wall, estimated to cost $119 billion, from the Rockaways in Queens across New York Harbor to New Jersey, in order to protect New York and New Jersey from storm surges. New York City would rely on federal funding for this project, but the Trump administration halted a study by the Army Corp of Engineers to look at the best way to protect New York from flood risks for a future project in February. In the meantime, there are other smaller projects moving forward. In 2019, funding for a barrier along the coast of Staten Island, the borough hit hardest by Hurricane Sandy, was approved. The NYC government acted on its own by approving a 2.5-mile barrier along the Manhattan side of the East River to protect the east side of Manhattan. Known as the East Side Coastal Resiliency Project, the project will cost the city $1.8 billion. The barrier will raise East River Park, a 57.5-acre public park stretching along the East River of Manhattan from Montgomery Street to East 12th Street, about 8 feet. Under the plan, there will be a series of berms, levees, walls, and green spaces added which will rise up to 16 feet. Although the New York City Council voted in November to approve the project and $511 million and $305 million have been committed by the U.S. Department of Housing and Urban Development and New York state respectively, it is now threatened by a lawsuit. A coalition of environmental and community groups filed a lawsuit with the Manhattan Supreme Court, claiming that the city failed to seek "parkland alienation" approval from the state legislature to allow a park to become a construction zone.

In Miami, federal officials are considering a $8 billion plan to protect Miami-Dade County from storm surge. The project would include 10-foot walls by the coast, which would span miles of streets currently lined with thousands of homes and businesses. However, to get the land it needs for the walls, the Army Corps of Engineers needs sign-off from local governments to seize more than 350 properties through eminent domain, which may severely impact the developers who have buildings in those areas. Although Miami is yet to evict residents, many local governments around the country have already agreed to the use of eminent domain to secure funding for resilience projects, a sign of how serious the threat of climate change has become to coastal cities.

Figuring out a fair way to pay for these types of large-scale climate change adaptation infrastructure projects is and will continue to be an issue. Since sea barriers only protect a certain

city or area, it is difficult to have the federal government pay for the whole project because only a certain area of the country will benefit from the project. Currently, the federal government, through the Army Corps of Engineers, pays for two thirds of resilience infrastructure projects like the building of seawalls and levees. Municipal government usually pays for the rest.

Moreover, adaptation investments don't have any real upside to them; they strictly protect against potential future losses. Investments in resilience do not does not have a return-on-investment that can attract private capital. Unlike greenhouse gas mitigation, which is heavily centered on transforming energy markets and attracts more than $300 billion a year globally in private investment in clean-energy production, much of the investment in resilience and adaptation is for public infrastructure that has to be paid for from government revenue.

This suggests that it will likely come down mainly to state and local governments to share the costs of these projects. While cities may be able to rely on partial funding from the federal government for some projects, cities will need to come up with innovative funding solutions to pay for these types of projects. In Miami, lower property values and higher insurance could lower revenues and make bond-issuing more expensive in the future, so the city is taking action now to turn climate change into an economic opportunity while the city's economy is still growing.[84] Its Miami Forever Climate Ready report outlines a strategy of taxing waterfront areas to pay for protection from hurricane storm surge and sea level rise, hiking impact fees on new development and starting a city fund for future resilience efforts. Miami is also working on ways to help citizens pay for adaptation projects like planting mangroves on the waterfront or raising sea walls by giving them federal or private sector options or by creating a city-owned revolving loan fund. In order to pay for resilience projects moving forward, there will need to be more innovations in climate-resilience financing to more fairly share the costs between city, state, and federal governments and the private sector.

Section 5. Recommendations:

Companies Should Have Its Own Property by Property Climate Risk Assessment

Currently, many real estate investors and developers are relying on others, especially insurance companies, to assess the climate risk of their properties, or are just looking at the FEMA flood map to have a vague idea about the climate risk level of the area where their properties are located. However, over-reliance on insurance providers or the FEMA flood map places investors at a disadvantage because they are unable to obtain customized climate risks specifically for their buildings. They are also unable to predict that the insurance premium will increase in the next year due to changes in

[84] Harris, A. (2020, January 23). Miami's plan to survive impacts of climate change: figure out a way to pay for it. Retrieved April 20, 2020, from https://www.miamiherald.com/news/local/environment/article239561543.html

projected climate risks. Therefore, real estate developers and investors are suggested to have their own property-by-property climate risk assessment either by building their own in-house risk assessment models to properly incorporate climate risks or by contracting with consulting firms that can provide them with customized climate risk analysis. Without solely relying on insurance companies and the FEMA flood map for climate risk analysis, investors and developers can assess properties' risks and value more precisely and they may be able to predict a potential increase in insurance premium and insurance availability due to climate risks to adjust their investment decision accordingly.

Analyze Climate Risk Better and Price It Properly

In addition to improving their internal risk analysis, investors and developers should also seek cooperation with third-party companies, such as research institutions and consulting firms. By relying on their more powerful databases and advanced analytical capabilities, companies should incorporate climate risk as a very important part in their decision making and price risk properly, whether through scenario analysis or quantitative models. Moreover, companies should be more cautious about investment in high-risk areas and take more aggressive actions. For example, the company should divest assets in locations where the return of this investment is very likely to be negative after considering the climate risks comprehensively.

Bridge the Gap Between Data Providers and Data Users

Since real estate investors and developers pay more attention to climate change risk assessment on their existing assets and new investment, they require more precise risk evaluation and predictions than in the past.

According to our respondents, the most precise climate change research and risk predictions provided by research institutions and raw data providers are not well-suited for their needs. Much of the terminology associated with climate information is confusing. To be useful for decision makers, climate prediction information should be provided with certainty (or uncertainty) quantified in a clear, understandable presentation or format.

Third-party consulting firms are now building the bridge between both ends. They customize scientific data and information into 'market language' that is acceptable by the real estate investors and developers. However, it can be costly for some of the short-term holders to acquire these kinds of services. We suggest that investors and developers directly collaborate with research institutions and raw data providers. Climate information is most effectively developed and applied through partnerships between climate information providers and decision makers (investors and developers). Research institutions themselves should take the role of "science integrator" in order to bridge the significant gap between the climate scientist and the consumer of climate information. To successfully gain an understanding of the consumer's information needs and applications, education and experience in both applications of climate science and the use of analytic tools is necessary on both ends.

Engage with governments and research institutes in designing and implementing city-wide resiliency plan

Much of the resiliency planning being done in New York City and Miami is currently being done by the public sector, along with non-profit research organizations like the Urban Land Institute, the Rockefeller Foundation or the Urban Green Council. Ongoing resiliency projects like the East Side Coastal Resiliency Project in New York are being planned mostly by the city government, and funded by the city, state, and federal governments. Real estate companies should be engaging with governments and helping finance these kinds of projects through public-private partnerships. This is happening in the city of Boston, where the private sector is being asked in a plan called Resilient Boston Harbor to pay for a significant portion of resilience infrastructure being proposed. These plans include raising city streets in South Boston and Dorchester and building 67 acres of green space and seawalls, much of which will be on the privately-owned sections of Boston's Harborwalk waterfront trail. These types of public-private partnerships are still relatively uncommon.

Additionally, there is a great deal of legislation surrounding building carbon emission reduction being passed, but not nearly as much clear-cut, mandatory steps being implemented surrounding adaptation. In New York, for example, Local Law 97, which sets limits on carbon emissions for buildings greater than 25,000 square feet, is forcing the commercial real estate industry to take quick and decisive steps to retrofit its buildings to fall in line with new emissions requirements. When it comes to adaptation and resilience measures, however, the recommendations from task forces and panels are often nebulous and non-compulsory. For example, Miami (along with Miami Dade County, Miami Beach, and the Rockefeller Foundation) released a comprehensive resilience plan in May 2019, which had been in the works for over three years. It was at least the sixth such plan published by the City of Miami/Miami-Dade County since 2012, according to WLRN, and there is a sense of "plan fatigue" when it comes to climate change adaptation. The plan repeats familiar calls for fixing aging flooding infrastructure, improving natural resilience, and making a further plan to deal with sea level rise; it also proposes 59 "specific actions" that are already in place. There is nothing in the plan that is mandatory, and it doesn't cite estimated costs for any of the actions recommended. The scope of the plan, while ostensibly a resilience plan, also went beyond climate impacts: it discusses issues like youth violence and the opioid epidemic. Resilience plans should involve the private sector, make clearer suggestions with estimated costs associated with them, and include a clear strategy to actually implement these plans.

Appendix

Appendix 1: Interviewee List

Type	Interviewee	Headquarters	Private/Public	Property Location	Property Size
Developer	New York-based real estate developer 1	New York	Non-traded Public	New York	20-30 million square feet (mostly office, some residential and retail)
	New York-based real estate developer 2	New York	Public	New York, San Francisco, Chicago	20-30 million square feet (mostly office, some residential and retail, etc.)
	New York-based real estate developer 3	New York	Private	US, Europe, Latin America, Asia	20-30 million square feet in New York City (mostly office, some residential)
	Miami-based real estate developer	Miami	Private	Miami	Over 1 million square feet
	Global logistics	San Francisco	Public	North America, South America, Europe, Asia	Around 1,000 million square feet worldwide
Investor	Global real estate investor 1	New Jersey	Private	Four continents	Over US$150 billion
	Global reat estate investor 2	New York	Private	North America, Europe, the Middle East, Africa, Latin America, Asia	Over US$100 billion (estimated)
	Asian Sovereign Wealth Fund	Asia	Private	Over 40 countries including New York and San Francisco	-
	European Pension Fund	Europe	Private	-	-
Insurer	Insurance Professional	Columbia University adjunct professor who has profound experience in advanced analytics at major insurance companies			
Consulting Firm	DeltaTerra Capital	An investment research and consulting firm serving institutional clients that seek to mitigate climate risk exposure and integrate climate-driven strategies in portfolios			
Scientific Institution	First Street Foundation	A nonprofit research and technology group who quantify and commnunicate America's flood risk based on the latest scientific analysis.			
	Digital Coast	Free website sponsored by the U.S. National Oceanic and Atmospheric Administration (NOAA), which provides U.S. coastal data, tools, training, and other information that are helpful for communities to address coastal issues			
	The Earth Institute	Senior Staff Associate of International Research Institute for Climate and Society who has profound experience in climate change risk projections			

Appendix 2: Climate risk analysis firms and their products

The following climate risk analysis firms offer the services that enable real estate developers and investors to assess asset-level to portfolio-level climate risk in financial terms by various locations, time periods, and emissions scenarios.

Four Twenty-Seven[85]	Founded: 2012 HQ: Berkeley, California The company provides climate risk scores for listed securities, and site-specific risk assessments for real assets, and intelligence services for scenario analysis, market opportunities, and resilience strategies. Its clients are financial institutions, Fortune 500 corporations, and governments around the world. In July 2019, Moody's Corporation purchased the majority share in Four Twenty-Seven. Among its various products, the company offers two services for the real estate sector. One is the on-demand climate risk screening application that provides instant insights into the forward-looking climate risk exposure of real asset portfolios through an intuitive, browser-based interface. The other is, in partnership with GeoPhy (a real estate analysis firm), forward-looking analytics for global listed REITs and the underlying assets that comprise them.
Jupiter Intelligence[86]	Founded: 2017 HQ: San Mateo, California The company has gathered a world-class team of scientists and technology experts, including a Nobel Prize winner for climate change, the former head of Atmospheric Science at the National Science Foundation (NSF), and the former head of Search Analytics at Google. Its model predicts asset-level impact from flood, fire, heat, drought, cold, wind, and hail events at the less-than-one-meter resolution, and its predictions are available from present to over 50 years in the future. Predictions are probabilistic and scenario-based. Its current clients are from enterprise, finance, and public sector are located in New York, Florida, Houston, and Europe.
The Climate Service[87]	Founded: 2017 HQ: Durham, North Carolina Its Climanomics® analytics system quantifies asset-level to portfolio-level climate risk, including both transition risk and physical risk, in financial terms that are aligned with the Task Force on Climate-Related Disclosures (TCFD). Its software has global coverage, spans decadal time periods from 2010 to 2100 across various emissions scenarios. In September 2019, Wells Fargo Startup Accelerator invested in The Climate Service.

[85] Four Twenty Seven. http://427mt.com/
[86] Jupiter Intelligence. https://jupiterintel.com/
[87] The Climate Service. https://www.theclimateservice.com/

Carbon Delta (MSCI company)[88]	Founded: 2015 Former HQ: Zurich Current HQ: New York The MSCI Climate Value-At-Risk (Climate VaR) is a tool to create more climate-resilient portfolios, protect assets from the worst effects related to climate change, and help identify innovative low carbon investment opportunities. The tool covers more than 10,000 companies, assessing all their associated equities and corporate bonds within the analysis. Its clients are investment managers, asset owners, banks, and insurance companies. For asset owners, the company provides insight into long-term climate change impacts with regards to asset allocation, direct investments, and investments in external managers.
DeltaTerra Capital[89]	Founded: 2019 HQ: Natick, Massachusetts The founder, David Burt, has spent more than 20 years helping institutional investors get the most out of their real estate and structured finance investments. Its Climate Risk Impact Metrics measure the impact of different climate change scenarios on real estate investments, mortgage securities, and related derivatives.

[88] Carbon Delta. https://www.carbon-delta.com/
[89] DeltaTerra Capital. https://www.deltaterracapital.com/

Appendix 3: Free-access flood risk assessment tools

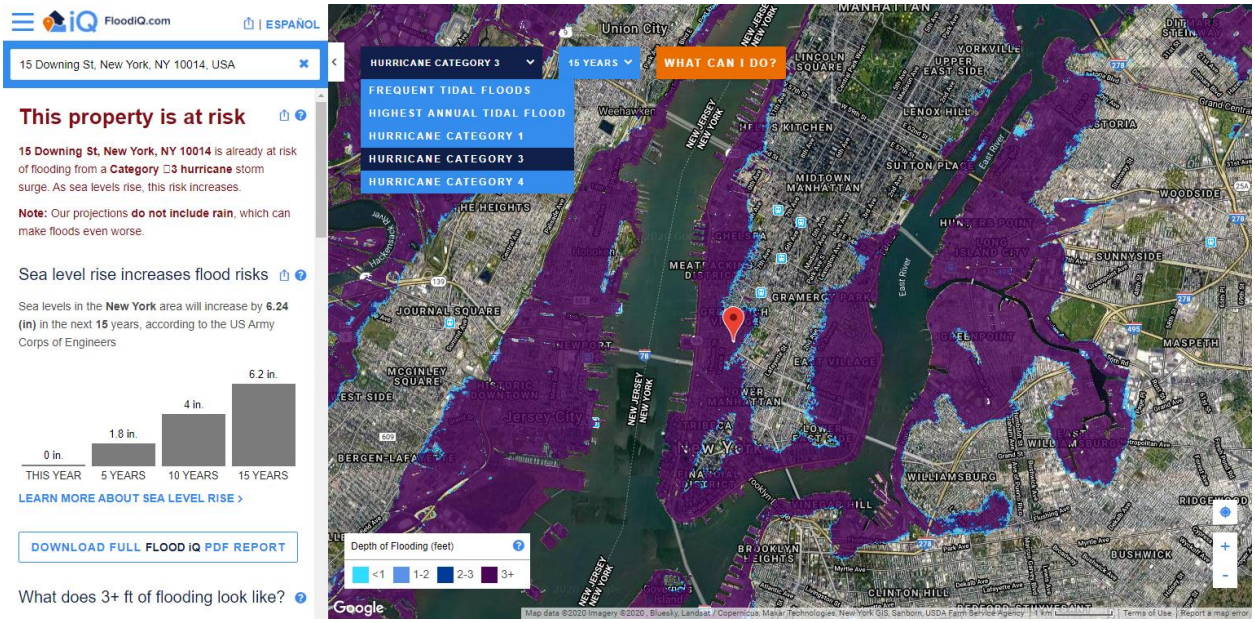
The following organizations offer the free-access tools that enable real estate developers and investors to assess the flood risks of their properties by various time periods and scenarios.

First Street Foundation[90][91]	The First Street Foundation is a New York-based nonprofit research and technology group founded in 2016. Its mission is to provide complete flood risk information to experts, policymakers, and American citizens in response to the situation that the FEMA flood map is underestimating the true risk. First Street Foundation creates its original flood model that shows present and future flood risks caused by tide, storm surge, rainfall, and riverine. The model was created by over 70 experts from Columbia University, Fathom, the Massachusetts Institute of Technology, Rhodium Group, Rutgers University, the University of California–Berkeley, and the University of Bristol. FloodiQ is its first interactive online tool created for the understanding of coastal flood risk associated with nuisance tidal flooding, the highest annual flood event, and worst-case scenario hurricane events. This visual map shows flood risk by various scenarios (frequent tidal floods, highest annual tidal flood, hurricane category 1, 3, and 4) and by year (this year, five years, ten years, 15 years). FloodiQ also shows detailed information on property risk levels, and the users can download the full report for each property. Currently, the First Street Foundation is developing a more comprehensive flood risk assessment tool called Flood Factor, which is to be released in Q2 2020. Flood Factor is a free, online tool that makes it easy for every American to understand if a property has flooded from major events in the past, is currently at risk, and how that risk changes over time. FloodFactor has some remarkable benefits of being a) national with multiple sources of flooding being taking into account (river, rain, surge, tide), b) higher resolution (3m property level resolution), c) introduces climate change and environmental risk factors into the modeling, and d) highly user friendly.
Digital Coast[92]	The Digital Coast is managed by NOAA's Office for Coastal Management and was first released in 2007. The Digital Coast provides various coastal data, tools, training, and other information with the US coastal management community. The Coastal Flood Exposure Mapper is an online visualization tool that shows the coastal hazard risks and vulnerabilities. The tool shows a comprehensive flood risk concerning several factors; high tide flooding, high risk and moderate risk flooding (designated by the FEMA), storm surge for category 1 through category 3 hurricanes, sea-level rise scenarios of 1, 2, and 3 feet, tsunami run-up zones. The Sea Level Rise Viewer is a web mapping tool to visualize community-level impacts from coastal flooding or sea-level rise (up to 10 feet above average high tides). The tool also shows the local sea-level rise scenario (intermediate low, intermediate, intermediate high, high, extreme) by year (2020, 2040, 2060, 2080, 2100).

[90] First Street Foundation. https://firststreet.org/
[91] FloodiQ.com. https://floodiq.com/
[92] Digital Coast. https://coast.noaa.gov/digitalcoast/

NYC Flood Hazard Mapper[93]	The New York City Department of City Planning (DCP) released the NYC Flood Hazard Mapper in 2017. The map provides a comprehensive overview of the coastal flood hazards that threaten the city today, as well as how these flood hazards are likely to increase in the future with climate change. It is intended to enable more informed decision-making by residents, property and business owners, architects and engineers, and policy-makers. The map shows future flood plain projection and high tide projection in 2020, 2050, 2080, and 2100.

[93] NYC Flood Hazard Mapper. https://www1.nyc.gov/site/planning/data-maps/flood-hazard-mapper.page



FloodiQ Source: FloodiQ.com

Coastal Flood Hazard Mapper Source: Digital Coast

NYC Flood Hazard Mapper
Source: NYC Department of City Planning

Appendix 4: Sample Questionnaire of GRESB Resilience Module[94]

RS3

Does the organization have a systematic process to incorporate climate risk and resilience into planning, budgeting, evaluation, and/or similar activities?

- ○ Yes
  - ☐ Transition risk

Risks and opportunities are explicitly included in entity-level planning

- ☐ Budgeting
- ☐ Performance review
- ☐ Work plans
- ☐ Other: _____

  - ☐ Physical risk

Risks and opportunities are explicitly included in entity-level planning

- ☐ Budgeting
- ☐ Performance review
- ☐ Work plans
- ☐ Other: _____

  - ☐ Social risk

Risks and opportunities are explicitly included in entity-level planning

- ☐ Budgeting
- ☐ Performance review
- ☐ Work plans
- ☐ Other: _____

Can the entity provide evidence as an UPLOAD or URL?

- ○ Yes

UPLOAD or URL_____

Indicate where in the evidence the relevant information can be found____

- ○ No

- ○ No

[94] 2019 Resilience Reference Guide. (n.d.). Retrieved from https://documents.gresb.com/generated_files/survey_modules/2019/resilience/reference_guide/complete.html

Appendix 5: GRESB Resilience Module Indicators[95]

RS1	Has the organization assigned responsibility for the climate risk and resilience of the entity to an employee and/or a team?
RS2	Does the organization have a systematic process for communication and review of resilience-related information by the most senior governance body with responsibility for the entity?
RS3	Does the organization have a systematic process to incorporate climate risk and resilience into planning, budgeting, evaluation, and/or similar activities?
RS4	Does the organization have a systematic process to assess the entity's exposure to climate-related transition risk?
RS5	Does the organization have a systematic process to assess the entity's exposure to physical climate risks?
RS6	Does the organization have a systematic process to assess the entity's exposure to social risks?
RS7	Has the organization assessed the potential financial impacts of climate-related risks on the entity?
RS8	Has the organization implemented resilience-related business strategies associated with the entity during the reporting year?
RS9	Did the organization have specific climate risk and/or resilience-related targets or goals associated with the entity during the reporting year?
RS10	Did the organization track specific climate risk and/or resilience-related performance metrics associated with the entity during the reporting year?

[95] Ibid., 79.

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