

Boston University

OpenBU

<http://open.bu.edu>

Boston University Theses & Dissertations

Boston University Theses & Dissertations

2023

Resilient real estate in the United States

<https://hdl.handle.net/2144/48432>

"Downloaded from OpenBU. Boston University's institutional repository."

BOSTON UNIVERSITY
GRADUATE SCHOOL OF ARTS AND SCIENCES

Thesis

RESILIENT REAL ESTATE IN THE UNITED STATES

by

JONATHAN GROBSTEIN

B.S., Boston University, 2021
B.A., Boston University, 2021

Submitted in partial fulfillment of the
requirements for the degree of

Master of Arts

2023

© 2023 by
JONATHAN GROBSTEIN
All Rights Reserved

Approved by

First Reader

James Baldwin, Ph.D.
Senior Lecturer of Earth and Environment

Second Reader

Sucharita Gopal, Ph.D.
Professor of Earth and Environment

Third Reader

Richard Reibstein, J.D.
Lecturer of Earth and Environment

RESILIENT REAL ESTATE IN THE UNITED STATES

JONATHAN GROBSTEIN

ABSTRACT

Environmental change is a major risk to the health and economic security of Americans, with impacts observed or anticipated on all sectors of the economy. The real estate sector is especially at risk from environmental change due to the complete immobility and relative illiquidity of land and building assets, which put property owners in local markets at risk, along with the national real estate market and the financial markets that depend on the steadily increasing value of real estate. The scale of the environmental risk to real estate across the United States represents a potentially catastrophic risk to the US financial system and macroeconomy. Government action is needed on an epic scale to protect Americans from the direct physical risks of environmental change along with the economic and social impacts that can negatively affect all Americans. This paper serves as an introduction to the topic of resilient locations and real estate, and the strategies that individuals, businesses, and governments can use to improve their resilience in the era of environmental change. The paper will add to the currently available literature and public information on the topic of climate change and real estate, by synthesizing publicly available information and drawing new conclusions using data analysis, to inform action on the part of individuals, businesses,

and governments to preserve their interdependent economic security. The paper will also provide a new definition for resilient real estate, in contrast with common definitions of sustainable real estate, sometimes called green buildings. Current definitions of resource-efficient buildings often leave out the most important topic when discussing climate change and real estate, the direct physical impacts and transition risks that put asset holders in vulnerable locations at extreme risk of income losses and property devaluations, whether the property has energy efficient appliances or not. A property should not be considered sustainable unless it is also resilient, and to be financially secure in the age of environmental change requires environmental resilience. Building new Class-A resource-efficient buildings in environmentally vulnerable locations is the opposite of sustainability; it adds to the value at risk, and due to the shorter building life cycle means resources are not used more efficiently over the life of a comparably resilient but inefficient asset.

As the quantity of quality, resilient land in the United States is declining, the population and economy are growing, and through the forces of supply and demand, prices are likely to increase for environmentally resilient land over the coming decades. Due to the spatially asymmetrical impacts of environmental change in the United States and the locationally fixed nature of real estate, the individual property owner and the macroeconomy are put at risk by the under accounting for environmental change in current asset prices. The uneven impacts of environmental change on real estate across the nation presents an opportunity to individuals, businesses, and governments to adapt using resilient real estate strategy.

TABLE OF CONTENTS

<u>SECTION I: ENVIRONMENTAL CHANGE AND REAL ESTATE</u>	1
INTRODUCTION	1
IMPERFECT RISK PROJECTIONS AND EARLY ADAPTATION TO ENVIRONMENTAL CHANGE	6
THE LANGUAGE OF ENVIRONMENTAL CHANGE	8
US ENVIRONMENTAL RISK UPDATE: OBSERVED CHANGES AND ECONOMIC IMPACT PROJECTIONS	9
US ENVIRONMENTAL CHANGE RISK UPDATE: ASSUME 2°C OF WARMING THIS CENTURY ABOVE PRE-INDUSTRIAL TEMPERATURES	14
THE IMPACTS OF ENVIRONMENTAL CHANGE ON REAL ESTATE	18
INCREASING TEMPERATURES, EXTREME HEAT EVENTS AND REAL ESTATE	19
FLOODING, HURRICANES, SEA LEVEL RISE AND REAL ESTATE	21
WILDFIRE RISK TO REAL ESTATE	24
FIGURE 1: NATIONAL FIRE RISK MAP (FIRST STREET FOUNDATION, 2022)	26
FRESHWATER AND DROUGHT	28
OTHER ENVIRONMENTAL RISKS	31
SPATIALLY DIVERSE RISK AND MAPPING RISK AND RESILIENCE	32
FIGURE 2. NATIONAL RISK INDEX MAP (FEMA, 2021)	33
FIGURE 3. PROJECTED ECONOMIC DAMAGE FROM CLIMATE CHANGE BETWEEN 2040-2060. (SHAW AND LUSTGARTEN, 2021)	35
REAL ESTATE VALUE: LAND RENTS, MARKET VALUE, INCOME CAPITALIZATION, AND CLIMATE CHANGE	36
WHY DOES LAND HAVE VALUE? LITERATURE REVIEW ON LAND RENTS THEORY	36
SUPPLY AND DEMAND FORCES AND RESILIENT REAL ESTATE	41
THE VALUE OF RIGHTS ASSOCIATED WITH REAL ESTATE OWNERSHIP	42
LITERATURE REVIEW OF METHODS FOR DETERMINING PROPERTY MARKET VALUE	45
INCOME CAPITALIZATION: HOW ENVIRONMENTAL CHANGE CAN IMPACT THE VALUE AND PROFITABILITY OF COMMERCIAL REAL ESTATE	47
FIGURE 4. IMPACTS OF CLIMATE RISK ON REAL ESTATE ASSET PERFORMANCE (CLAYTON, 2021 REFERENCING WILDE AND COLEY, 2011)	48
Table 1: The Effect of Environmental Risk on Profitability, Income, and Expenses	49
TRANSITION RISKS VS. PHYSICAL ENVIRONMENTAL RISKS TO REAL ESTATE.	53
THE SYSTEMIC RISKS TO REAL ESTATE AND THE MACROECONOMY: THE NEXT REAL ESTATE-FINANCIAL CRISIS?	54

FINANCE, INSURANCE, REAL ESTATE, ENVIRONMENTAL CHANGE AND THE NEXT FINANCIAL CRISIS	67
INTRODUCTION TO THE IMPENDING ENVIRONMENTAL CHANGE-INDUCED REAL ESTATE-FINANCIAL CRISIS	68
Table 2: Real Estate Building Value by State Categorized using FEMA Risk Rating	73
SHORTCOMINGS OF CURRENT REAL ESTATE SUSTAINABILITY EFFORTS AND THE COBENEFITS OF ADAPTATION AND MITIGATION	74
<u>SECTION II: RESILIENT REAL ESTATE</u>	<u>78</u>
RESILIENT REAL ESTATE: AN INTRODUCTION	78
WHAT IS RESILIENCE?	79
DEFINING THE CATEGORIES OF RESILIENT LOCATIONS AND PROPERTY	80
THE LEVELS OF ENVIRONMENTAL RISK AND RESILIENCE	81
PROPERTY-LEVEL RESILIENCE	82
COMMUNITY-/CITY-/COUNTY-LEVEL REAL ESTATE RESILIENCE SOLUTIONS	87
FIGURE 5: MULTI-TIERED RESILIENCE SOLUTIONS GRAPHIC (CLIMATE READY BOSTON, 2021)	90
STATE-LEVEL RESILIENCE	90
FEDERAL-LEVEL RESILIENCE	91
ENVIRONMENTAL CHANGE, MIGRATION, AND REAL ESTATE	93
CLIMATE RESILIENT REAL ESTATE	96
MY DEFINITION OF ENVIRONMENTALLY RESILIENT REAL ESTATE:	97
NATIONAL RESILIENCE VS. LOCAL RESILIENCE	98
DEFINING NATIONALLY-RESILIENT PROPERTY	98
DEFINING LOCALLY-RESILIENT PROPERTY	100
10 EXAMPLES OF RESILIENT CITIES AND STATES IN THE UNITED STATES	102
Table 3: 10 Resilient States and 10 Resilient Cities Sample	103
Table 4: The 20 Most Resilient Counties in the United States - Projected Economic Damage from Climate Change (Shaw and Lustgarten, 2021)	105
Table 5: The 20 Most Vulnerable Counties in the United States - Projected Economic Damage from Climate Change (Shaw and Lustgarten, 2021)	106
<u>SECTION III – OPPORTUNITY FOR RESILIENT REAL ESTATE INVESTMENT IN THE ERA OF ENVIRONMENTAL CHANGE</u>	<u>107</u>
HOW SHOULD REAL ESTATE STAKEHOLDERS ADAPT TO THE CHANGING ENVIRONMENT? POLICYMAKERS	107
	107

INDIVIDUALS, INVESTORS, AND BUSINESSES	111
RENTERS	113
HOMEOWNERS	114
INVESTOR AND BUSINESSES - REDUCE EXPOSURE TO RISK AND TARGET RESILIENT LOCATIONS	115
THE ERA OF RESILIENT REAL ESTATE INVESTMENT	116
RESILIENT REAL ESTATE INVESTMENT STRATEGY	118
RESILIENT CITIES AND 'CLIMATE HAVENS'	119
RESILIENT RURAL LAND	121
CONCLUSION	125
WORKS CITED	127
CURRICULUM VITAE	137

LIST OF TABLES

Table 1: The Effect of Environmental Risk on Profitability, Income, and Expenses	49
Table 2: Real Estate Building Value by State Categorized using FEMA Risk Rating	73
Table 3: 10 Resilient States and 10 Resilient Cities Sample	103
Table 4: The 20 Most Resilient Counties in the United States - Projected Economic Damage from Climate Change (Shaw and Lustgarten, 2021)	105
Table 5: The 20 Most Vulnerable Counties in the United States - Projected Economic Damage from Climate Change (Shaw and Lustgarten, 2021)	106

LIST OF FIGURES

Figure 1: National Fire Risk Map (First Street Foundation, 2022)	26
Figure 2. National Risk Index Map (FEMA, 2021)	34
Figure 3. Projected Economic Damage from Climate Change between 2040-2060. (Shaw and Lustgarten, 2021)	35
Figure 4. Impacts of Climate Risk on Real Estate Asset Performance (Clayton, 2021 referencing Wilde and Coley, 2011)	48
Figure 5: Multi-Tiered Resilience Solutions Graphic (Climate Ready Boston, 2021)	90

SECTION I: ENVIRONMENTAL CHANGE AND REAL ESTATE

Introduction

Global environmental change is a major risk to the health and security of all Americans, with impacts observed or anticipated on all sectors of the economy, especially for communities in vulnerable locations and the individuals, businesses, and governments holding fixed assets in those locations (IPCC, 2022. NCA, 2017. NOAA, 2021. DoD, 2021. Clayton, 2021. FEMA, 2021). The real estate sector is especially at risk from environmental change due to the complete immobility and relative illiquidity of land assets, putting individual property owners in local markets at risk along with the national real estate market and the financial markets that depend on its stable value (UCS, 2018. First Street Foundation, 2022. Clayton, et al., 2021). The scale of the environmental risk to real estate across the United States represents a potentially catastrophic risk to the US financial system and economy (UCS, 2018. NCA, 2017). Government action is needed on an epic scale to protect Americans and their real estate from the direct physical risks of environmental change along with the market and social impacts that can harm the health and economic security of all Americans (NCA, 2017. IPCC, 2022. FEMA, 2021).

As an individual, to be considered 'resilient to environmental change' generally requires living in a home or apartment in a location that is relatively resilient as compared to the national average, both on a parcel and in a structure that is relatively resilient to its local market. This paper will serve as an introduction to the topic of resilient locations

and real estate, and the strategies that individuals, businesses, and governments can use to ensure their resilience in this current era of rapid and significant environmental change. This research will add to the currently available literature and public information on the topic of climate change and real estate, by synthesizing the public information and drawing new conclusions using data analysis, to inform action on the part of individuals to preserve their economic security.

The paper will also provide a new definition for resilient real estate, in contrast to common definitions of ‘sustainable real estate’ or ‘green buildings’. Current definitions of resource-efficient buildings often leave out the most important topic when discussing climate change and real estate, the direct physical impacts and transition risks that put asset holders in vulnerable locations at extreme risk of income losses and property devaluations, whether the property has energy efficient systems or not (USGBC, 2021. Clayton et al, 2020). This paper will make the case that a property should not be considered sustainable unless it is also resilient, and to be financially secure in the age of environmental change requires environmental resilience. Building new Class-A resource-efficient buildings in vulnerable locations is the opposite of sustainability; it adds to the value at risk, and due to the shorter life cycle means resources are not used more efficiently over the life of a comparably resilient but inefficient asset.

Due to the spatially asymmetrical impacts of environmental change in the United States and the locationally fixed nature of real estate, the individual property owner and the macroeconomy are put at risk. The uneven impacts of environmental change on real

estate across the nation presents an opportunity for individuals, businesses, and governments to adapt using resilient real estate strategy.

Environmental change is already affecting the value of real estate in certain vulnerable locations that are already experiencing severe impacts (Clayton et al, 2021. NCA, 2018). Several recent peer-reviewed studies on the topic of environmental risk and real estate in specific high-risk markets have come to similar conclusions that properties with extreme vulnerability are already seeing their values impacted negatively (Okmyung, 2010. Kousky, 2020). In the year 2023, Americans are suffering from the health impacts and economic damage caused by flooding, wildfires, drought, pests, and other environmental changes that are becoming more costly each year (NCA, 2018. First Street Foundation, 2021. UN-IPCC, 2022). The US Department of Defense views environmental change as one of the greatest threats to global security and American interests at home and abroad in this decade. The military considers the climate change crisis to be a 'threat-multiplier', increasing the likelihood of conflicts, food and water shortages, migrations, economic instability, and political instability around the world (DoD, 2021. UN-IPCC, 2022). Environmental change, in its many forms, threatens the health and security of all Americans, especially those who live in vulnerable locations (DoD, 2021. NCA, 2018, NOAA, 2021). Despite the extreme risks the United States will face in the years to come, the federal government has taken limited action to either address the causes of environmental change or to build resilience to the environmental changes Americans are already experiencing today.

Researchers are only beginning to make the connection between the projected impacts of environmental change and the implications of that research on individual property value, real estate market integrity, and structural risks to the national economy (Clayton et al, 2021. Pogue, 2021. etc). The limited public information may also be due to institutions and investors not wanting to spook individuals and markets, and many may already be implementing the strategies introduced at the end of this paper for hedging environmental risk using relatively-resilient property.

The topic of resilient real estate is a new idea and an old one. The idea is old in that humans have always adapted structures to their environmental conditions or faced the consequences for hundreds of thousands of years (Westling, 2022. Winchester, 2021). The idea is new in the sense that humans have not dealt with a rapid environmental change on a global scale of this kind in the recorded history of our species (UN-IPCC, 2022. Meadows et al. 1972, 2004). With modern technology and computer modeling humans can now predict with some confidence how the environment is likely to change under current assumptions of population growth, economic growth, and technological change (Meadows et al., 1972, 2004). Humans have extensive experience with rapid environmental change on a local scale that forces individuals to adapt their living conditions to survive, whether by adapting their structures, or their places of settlement, such as in the Dust Bowl in the 1930s when millions of domestic migrants crossed state lines to find a better chance at survival, or in the environmental disasters caused by poor central planning on the part of the Soviet Union and China during the Cold War (Nikolaidis, 2011). In modern times, environmental change has induced drought,

starvation, migration, and conflict in Syria, and other nations of the Middle East and Africa (UN-IPCC, 2022). Migration flows can often be attributed to environmental change, whether directly through drought, flood, or fire events or indirectly through conflicts and socio-economic instability induced by changes in the environment.

Environmental change in the 21st century is different than previous changes because of the global scale of the causes and consequences of climate change, the rate of change, the massive material needs of the largest human population in history that is continuing to grow along with its economy, and the severity of the likely consequences for humans and nations globally (UN-IPCC, 2022).

The need to look forward – to forecast future environmental changes – without a strong basis of past experience with rapid global environmental change makes action difficult to base entirely on current scientific evidence and can lead to a lack of public support and governmental action (IPCC, 2022). The technological tools to forecast future changes are valuable in that they can inform and induce action on the part of governments, businesses, and individuals, however, due to their forward looking nature, there will always be uncertainty. Humans will need to adapt with the information they have access to and make difficult choices without perfect information before the choices are made for them by man or nature.

This paper is meant to offer both a warning to Americans, businesses, and governments about the threats of environmental change and the necessary adaptations that must take place in the coming years to ensure our collective security and individual economic security. To ensure the economic security of the United States, the basis of our

economy, our people, and our land must be protected. Most Americans live in either a home or an apartment, and their health, safety, and economic security are linked to a single property. The American economy, on a macro scale, is built on top of the land, and its underlying financial system is built on top of the steadily increasing value of real estate (Winchester, 2021. Stein, 2019. Fox 2013). The security of the United States, and all individual Americans, is put at risk by the scale of the environmental changes to come (DoD, 2021. NCA, 2018. IPCC, 2022). This paper is meant to both inform and induce action on the part of individuals, businesses, and governments, toward a more resilient future for America.

Imperfect Risk Projections and Early Adaptation to Environmental Change

All projections have uncertainties, and environmental change projections are especially difficult, due to the complexity of earth systems and the fact that environmental change on this scale has not occurred this rapidly at any point in the history of humanity (IPCC, 2022. Meadows et al, 2004). We simply can't rely on historical information to project what will occur in the future because what is occurring has not happened before. For example, the IPCC projects a wide range of possible outcomes of sea level rise this century from 3 ft to over 10 ft, while other peer-reviewed research has reported that an estimated sea level rise of over 10 ft is likely this century (IPCC, 2022. Englander, 2021. NOAA, 2021). The difference between 3 ft and 10 ft is enormous in terms of the people and property at risk, the macro-risks, and the necessary adaptations to be resilient to the changes (UCS, 2018. IPCC, 2022. First Street Foundation, 2021). Uncertainty is an inherent part of forward-looking projections of

environmental impacts and changes in property value, but we must rely on uncertain projections because by the time the projections can be proven true, it will be too late to adapt in an orderly manner. The long life-cycle of real estate, with buildings and homes often taking years to construct and lasting for generations once completed, requires effective action to be taken before perfect information is available. The gap between projections and reality has started to tighten, as humans experience environmental change first hand, confirming scientists' earlier projections (IPCC, 2022). We must learn from these confirmations of prior scientific projections, and realize that institutional publications of environmental change projections will be conservative in nature and are thus likely to be proven accurate with time (Pogue, 2021. IPCC, 2022). The Federal government and the United Nations IPCC are conservative in their projections, partly due to the many stakeholders that must sign off on their publications, so it is crucial to rely on a mix of projections from a variety of sources, not only the largest institutions (IPCC, 2022. NCA, 2021. Englander, 2021. UCS, 2018. First Street Foundation, 2021). For example, the IPCC does not include several important factors in its projection of long-term global warming and sea level rise, in part because it will add uncertainty to their models (IPCC, 2021. Englander, 2021) In trying to provide a level of certainty in their projections, due to their conservative nature, there is a clear under-accounting for risk in publications from the largest institutions. There is no single source of information that is without bias or imperfection, but a combination of sources, with competing agendas, coming to similar conclusions, is the strongest form of evidence. We have no choice but to rely on imperfect information to adapt effectively to environmental change. The

science is not clear on how much damage environmental change will cause and the timeline for the damage; however, the science is very clear that environmental change will have significant impacts on the health and economic security of all Americans within a matter of decades.

The Language of Environmental Change

In this paper, I will generally refer to the risks surrounding climate change within a more encompassing and apolitical term, “environmental change”. It is the experienced environmental change that humans are already adapting to, a crisis that goes far beyond global warming to include changes in biodiversity, pollution, resource availability, freshwater availability, and other environmental changes that are not accurately captured in the term 'climate change'. Both academia and the media will often refer to environmental changes that are not directly attributable to global warming as being part of the ‘climate crisis’ realm; however, I believe it is more accurate and useful to refer to the ‘environmental change’ when discussing real estate resilience in this paper. This paper is not about the mitigation of greenhouse gas emissions in the real estate sector, or slowing global warming, which is already the focus of billions of dollars of research and investment around the world. This paper is about how individuals, businesses, and governments in the United States can adapt to the reality of environmental change today, to guard life and property through resilient real estate strategy. Adaptation solutions to environmental change frequently have co-benefits with carbon emissions mitigation methods, and some of those synergies will be mentioned to in this paper.

US Environmental Risk Update: Observed Changes and Economic Impact Projections

Environmental change is already affecting the American economy across many sectors, with the sectors that rely on fixed assets in vulnerable locations experiencing the greatest impact (Brunetti et al, 2021). The real estate sector, and the finance and insurance sectors that both facilitate real estate markets and rely on its stable value, are especially at risk from the impacts of environmental change (Brunetti et al, 2021. Sigaud, 2018).

The literature review to follow on the impacts of environmental change in the United States will outline the current and future environmental risks to Americans, focusing on those impacts that are likely to effect real estate value. For the outline of environmental risks, I will refer to a 2022 report from the United Nations' Intergovernmental Panel on Climate Change (UN-IPCC) and the U.S. National Climate Assessment (NCA) from 2018, as well as research from the Federal Emergency Management Agency (FEMA), the First Street Foundation, and the Union of Concerned Scientists (UCS). After outlining the risks, the research will describe how environmental change can impact the value of real estate in the United States.

In early 2022, the IPCC released the findings from its 6th Climate Assessment, which emphasized that the global climate is changing faster than previously anticipated by the group of 196 countries that comprise the United Nations IPCC (UN-IPCC, 2022). The world's leading scientists, economists, politicians, bankers, and companies around

the world have agreed that global temperatures are rising as a result of greenhouse gas emissions, and this represents a major risk to life, property, and security (UN-IPCC, 2022). The pledges made by the 196 countries are for the most part not being followed, and given current government plans, policies, and technology, it will be extraordinarily difficult to keep temperatures from rising beyond the 1.5-degree threshold of warming agreed upon in 2015 at the Paris conference (UN-IPCC, 2022). If global average temperatures exceed the two-degree threshold, which is now the most likely scenario, the projected impacts of the changing environment become even more catastrophic (UN-IPCC, 2022). Some of the more pessimistic scenarios of warming outlined in the IPCC adaptation report are of a magnitude that could put pressure on the survival of current human civilization as we know it, in a similar way to the dangers of nuclear weapons (UN-IPCC, 2022. Bendell, 2019. Englander, 2020).

Even with major emissions reductions in the coming years, global temperatures will continue to increase for decades, due to slow-moving earth system lag times, feedback loops, and residency times of greenhouse gases (UN-IPCC, 2022). The most recent UN-IPCC and NCA reports make it clear that humanity has run out of time to prevent devastating climate change, although the level of long-term devastation can be softened by increasing the rate of greenhouse gas emission mitigation (e.g. carbon emissions reductions, direct air capture, and storage) and adaptation solutions (e.g. building sea walls, sponge parks, managing a retreat away from risk). There will continue to be acute devastation in many vulnerable locations around the world as a result of environmental change, and that devastation will grow with time (IPCC, 2022).

Americans are already feeling the damaging effects of climate change on their health, property, and communities (NCA, 2017. Englander, 2020. Pogue, 2021). Americans are experiencing coastal flooding in Florida and New York, inland flooding in Appalachia, and drought and wildfire in the American West, this is a national crisis as well as a local one (UN-IPCC, 2022. NCA, 2017). Scientists, politicians, global organizations, media, and communities have been stating that 'it's now or never', for many years, but now the UN-IPCC and other major research institutions have the statistical evidence to say that humans can no longer completely avoid the devastating impacts of environmental change with greenhouse gas emission mitigation, as was once widely accepted (UN-IPCC, 2022). No matter what is done, humans will continue to face worsening environmental change for decades, with little chance of environmental stabilization this century (UN-IPCC, 2022). Americans can both accept that the environment is changing and adapt to the new reality by building resilience into our society, while also continuing to speed up greenhouse gas emission mitigation to limit the long-term risk to global human civilization (UN-IPCC, 2022. NCA, 2018. NOAA, 2021. Pogue, 2021. Bendell, 2018). Individuals and communities must build resilience and mitigate carbon simultaneously to maximize personal security and financial security in the era of environmental change.

Investment in 'sustainability' without considerations of long-term resilience, or vice-versa, is a losing strategy for sustainability and economic continuity in high-risk locations (UN-IPCC, 2022. NCA, 2017. UCS, 2018). On-site or community carbon mitigation does little to reduce the risk of long-term property value depreciation in high-

risk locations without local adaptation/resilience solutions to counter environmental change impacts on the ground.

The impacts of environmental change – including the impacts of global warming – that threaten the US economy and the health of Americans include the increases in the severity of extreme heat events, sea level rise (SLR), extreme precipitation events, wildfires, biodiversity loss, devastating droughts, limits to the availability of freshwater, and loss of quality topsoil (NCA, 2017. Meyer, 2019. IPCC, 2022). Environmental change will not harm every community, area, region, or economic sector in the same way, or at the same time. Many parts of the US are at low risk of environmental hazards and may see some economic benefits from warmer temperatures (Pogue, 2021). Specific areas within the United States face such severe risk that they are unlikely to be able to support prosperous habitation long-term, such as low-lying areas in New Orleans, Miami, Houston, and New York (UCS, 2018. First Street Foundation, 2021). Cities represent a tremendous amount of the economic wealth and prosperity in the US, and as more people move to cities, this is where most people will face the effects of environmental change firsthand, and where most of the real estate losses will occur (UCS, 2018. First Street Foundation, 2021).

Multiple efforts on the topic of resilient assets and real estate are underway in academia and the business world, but it is an area of study that is still in its earliest stages. Three sources, in particular, get to the heart of the topic of interest: a McKinsey & Company report titled *Climate Risk and the Opportunity for Real Estate* (2022); a recent book titled *How to Prepare for Climate Change*, authored by David Pogue (2021); and a

scientific report released by the Union of Concerned Scientists titled *Underwater* (2018). The McKinsey report presents the risks to real estate in two distinct forms, the physical risks, such as stormwater flood damage or fire, and the transition risks, such as higher insurance premiums, changes in demand, fines for inefficient energy use, and higher taxes to fund local resilience (Boland, et al, 2022). *How to Prepare for Climate Change* goes beyond explaining the vulnerabilities and impacts of environmental change on the U.S. economy, and gives actionable guidance for individuals and property owners on how to adapt. Pogue explains how readers can build resilience, and crucially, where they can go to avoid the worst impacts of environmental change in the US (Pogue, 2021). Pogue focuses on numerous criteria and provides a list of cities that are relatively resilient to environmental change in the US. The cities chosen are the ones that have been highlighted by multiple reports as being particularly resilient to environmental change within the United States. The resilient locations highlighted in *How to Prepare for Climate Change* include Burlington, Vermont; Cleveland, Ohio; and Ann Arbor, Michigan (Pogue, 2021). The 2018 report from the Union of Concerned Scientists focuses on the scale of the risk to real estate across the United States and estimates the value-at-risk for individual regions and the real estate market as a whole (UCS, 2018). This report on real estate vulnerability makes it clear that there are severe risks in the real estate market across the country at a scale that could pose risks to the entire US financial system and wider economy (UCS, 2018. Meyer, 2019).

Real estate underpins the overall economy and cannot be moved, making it more vulnerable to local environmental hazards than other asset types (Clayton et al, 2021).

The scale of that risk is so large that it could put the entire economy in danger (UCS, 2018). This paper will focus primarily on residential real estate, and to include multi-family properties – with more than four dwelling units – in that analysis, even though these apartment buildings are often described as commercial real estate in a market and legal context. Extensive research has been published on the current and projected effects of natural hazards on residential real estate, whereas less research has gone into projecting the impacts of environmental change on commercial real estate (e.g. retail, office, industrial, etc.). It can be more difficult to predict how the impacts of environmental change will affect commercial real estate value over the long term, especially for certain types of commercial real estate such as office, industrial, and bio-lab space. The value of these types of commercial real estate generally rely on the factors of agglomeration and intra-sector economic cycles that make it difficult to accurately project how environmental change will impact value over the long term.

US Environmental Change Risk Update: Assume 2°C of Warming this Century above Pre-Industrial Temperatures

In 2022 the UN's International Panel on Climate Change released the findings from its 6th climate assessment, with a grave assessment that the global climate is changing faster than previously anticipated by the group of scientists representing 196 countries, and the hopes of significantly mitigating the impacts of the climate crisis during our lifetime are slipping away (UN-IPCC, 2022). Global temperatures are continuing to rise and previous emissions reduction targets are not being met, all while our world's leading scientists and mathematicians find that even if we reached net-zero

carbon emissions by 2025, the earth would continue warming for many decades (UN-IPCC, 2022. Tollefson, 2018). Due to current greenhouse gas emissions, a lack of action on the part of global governments, increasing global standards of living, and other factors, the UN-IPCC has concluded that it will be extraordinarily difficult for humanity to keep temperatures from rising beyond the Paris Climate Accords threshold of 2°C warming above pre-industrial temperatures, let alone the initial goal of 1.5°C that many are still clinging to blindly (UN-IPCC, 2022). If global average temperatures exceed that two-degrees-celcius threshold, the projected impacts of the changing climate will be devastating to all nations of this earth (UN-IPCC, 2022).

Even with major emissions reductions in the coming years, global warming will continue for decades due to slow-moving earth systems, feedback loops, and residency times of greenhouse gasses (IPCC, 2022). Based on the most up-to-date science from leading institutions, it is clear that humanity can no longer fully prevent devastating environmental change. The report from the IPCC and other major institutions also make clear that the level of devastation can still be reduced by greenhouse gas emission mitigation, and adapted to with resilient solutions. No matter the pace of greenhouse gas emission mitigation, the acute devastation already experienced in many environmentally-vulnerable locations around the world will continue to get worse (UN-IPCC, 2022). For environmentally-vulnerable locations, adaptation is quickly becoming the only hope for long term prosperity and economic survival.

To be prepared for the environmental changes to come, communities must build resilience and mitigate carbon simultaneously to be adequately prepared for the uncertain

times ahead. Greenhouse gas emission mitigation and resource efficiency, often referred to broadly as ‘sustainability’ without adaptation and resilient improvements is now a losing bet in environmentally-vulnerable locations (UN-IPCC, 2022). Local carbon mitigation does not reduce local environmental risk (usually), so it can be easier to justify defensive resilience measures over decarbonization (UN-IPCC, 2022). Within the United States, communities and people of all types will face hardships they are not prepared for, with some densely populated parts of the United States becoming largely uninhabitable within decades (UN-IPCC, 2022. UCS, 2018. NCA, 2017. Pogue, 2021).

Environmental change impacts on the US economy include flooding, fires, extreme heat, biodiversity loss, and droughts (NCA, 2018). Environmental change will not harm every community, area, region, or economic sector in the same way, or at the same time. Many regions and individual locations within the US are at a significantly lower risk of environmental hazards, and could see some economic benefits from the warmer temperatures and worsening conditions in other locations (Shaw and Lustgarten, 2020. Reade and Bendell, 2021). Some areas are under such severe risk that they are unlikely to be able to support prosperous habitation long-term, such as New Orleans or Miami (UCS, 2018). High-risk cities around the US represent a tremendous amount of the economic wealth and prosperity in the US, with many assets stuck in place as real estate or infrastructure (UCS, 2018).

The real estate sector underpins much of our overall economy and financial system and is both a major creator and storer of wealth for millions of American homeowners, but most importantly to this paper, land cannot be moved and large

structures typically cannot be moved without costly transplants. Every building is set in a unique location, on a unique lot, and is usually stuck in that place for its lifetime. In contrast, after a natural disaster occurs, some people and businesses can relocate elsewhere to reduce the impacts of the damage on their health. People and businesses can be considered more mobile than real estate, however in reality many businesses and individuals are tied to a location and cannot move easily, in similarity to real estate. Mobility and liquidity will allow certain sectors of the economy, business types, and Americans to move away from risk, especially multinational corporations and wealthy citizens. The real estate sector isn't going anywhere, as long as people want to live in a place or do something useful there, the land will continue to have value. Owners of vulnerable real estate will need to improve the resilience of their assets, or choose instead to retreat to a less vulnerable area. At a certain point, for the most vulnerable locations, a managed retreat can become the only survivable option.

“With the world’s sea levels rising fast, the assumption that land is the only thing that can’t fly away, or the only thing that lasts, is for the first time now shown to be demonstrably false. The belief in land’s limitless stability has informed humankind’s approach to the possession of the world’s surface for centuries past...but now a profound change is coming”.

(Winchester, 2021).

Real estate, by its nature, cannot be moved to avoid future risks or capitalize on opportunities. Real estate can be sold, but only when a buyer is willing to pay an acceptable price. In most recorded history land is thought of as a finite, forever-lasting

resource on which society is built, but that idea must be tweaked for modern reality (Winchester, 2021). American land has been increasingly degraded and swept away by rising seas, runoff into waterways, burned through, or soured by invasive pests (NCA, 2019. Winchester, 2021). US land resources are vast but limited, and those resources are declining due to the many impacts of humanity on the environment. As the quantity of quality land in the United States is declining, the population and economy are growing, and through the forces of supply and demand, prices are likely to increase for resilient land over the coming decades.

The Impacts of Environmental Change on Real Estate

The impacts of human-induced environmental change include extreme heat, drought, wildfire, sea level rise, increased storm severity, flooding, ocean acidification, biodiversity loss, and many lesser-known risks that do not get as much attention but can be equally as devastating to certain locations, such as the changing habitat of mosquitoes and agricultural/timber pests (IPCC, 2022). The following pages will describe a few of those risks that have been studied extensively and have impacts on real estate that can be projected forward with reasonable confidence, including extreme heat, flooding, freshwater availability, and wildfire. Due to the extensive research available on the impacts of environmental change in the United States and around the world, this paper will provide a basic introduction to each of these four impact types and explain how they can impact real estate in the United States. The section will also highlight the currently available research with statistical evidence to suggest that environmental changes are

already putting negative pressure on values in specific locations and that the scale of risk represents a macroeconomic risk to the United States economy.

Increasing Temperatures, Extreme Heat Events and Real Estate

Global warming means the average temperature around the world is rising each year. Higher temperatures lead to several different environmental changes that can impact real estate by bringing more flooding and wildfires (IPCC, 2022. UCS, 2017). In certain locations, the temperature difference itself is becoming more dangerous to life and property, as extreme heat events cause illness and death (Luber and McGeehin, 2008. UN-IPCC, 2022.).

Extreme heat can have a multitude of negative effects on the human body including dehydration, stroke, and death, while also decreasing the productivity of workers and students. Extreme heat can also threaten the lives of heat-vulnerable plants and animal species, lead to an increase in energy demand for cooling, and increase the likelihood of flooding, fire, and drought (UN-IPCC, 2022). Extreme heat makes life more difficult for those beings that have not adapted to sustain themselves in that type of environment. For a community/society, extreme heat can be a major obstacle to providing food, energy, water, and emergency services that keep the community functioning and the citizens healthy (Luber and McGeehin, 2008. UN-IPCC, 2022).

“Despite the high mortality associated with EHE (extreme heat events) and projections of a warming climate, there is a lack of public recognition of the hazard of extreme heat exposure, and U.S. metropolitan areas generally lack preparedness measures such as heatwave-response plans. Part of the problem lies in the fact that heatwaves are silent killers—natural disasters that do not leave a trail of destruction in their wake” (Lubin and McGeehin, 2008).

This paper from Lubin and McGeehin goes on further to describe the proven increase in the occurrence and severity of extreme heat events in the US, as well as the widely researched urban heat island effect that makes temperatures in cities warmer than the surrounding suburbs (*Lubin and McGeehin, 2008*). The risk of extreme heat is greatest in locations that are already very hot, including the majority of the Southwest and Southeast United States, however, cooler regions can be at risk from lack of preparedness (FEMA, 2021).

The elderly and children in buildings without air conditioning are especially at risk from extreme heat events, and in locations without a history of such events, that is a widespread risk across the states (FEMA, 2021).

Extreme heat events can have extensive economic impacts: overloading the power grid, increasing utility and maintenance costs, and grounding commercial airplanes. A direct link between the value of location and extreme heat in the United States has not been found, but it can be logically assumed that if in 2023 it is difficult to work or walk outside without shade or water for an hour then rising temperatures will negatively impact the quality of life and economy of the location, putting downward pressure on the value of real estate.

For a sense of the scale of the extreme heat risk across the United States, a recent study from the First Street Foundation (a non-profit research and technology group that publishes environmental risk reports for U.S. real estate) analyzed property-level heat risk data and determined that 50 counties, home to 8.1 million people, are expected to

experience temperatures above 125°F at least once during the year in 2023. By 2053, 1,023 counties are expected to exceed this temperature, home to 107.6 million Americans and covering a quarter of the US land area” (First Street Foundation, 2022). This region of fast-growing extreme heat risk, concentrated in a geographic area the group calls the "Extreme Heat Belt," stretches from the Northern Texas and Louisiana borders to Illinois, Indiana, and into southern Wisconsin (First Street Foundation, 2022). The areas that have a history of moderate temperatures that are beginning to see more instances of extreme heat can face more risk than those areas that have developed around living with extreme heat. Areas where air conditioning is uncommon and local governments lack emergency response plans for extreme heat are especially at risk from higher temperatures and more extreme heat events. The growing likelihood of extreme heat events as a result of climate change is a risk that cannot be ignored for real estate decision-makers in the southern states that are the hottest in the United States, as well as for northern states that are not well prepared for these events.

Flooding, Hurricanes, Sea Level Rise and Real Estate

As global average air temperatures increase, the frozen freshwater of the polar regions melts, and flows down into the oceans, causing the sea level to rise. The measured increase in global average ocean temperatures also leads to an expansion in the volume of water, causing sea levels to rise even more than can be attributed to meltwater alone, and this warmer water also brings with it bigger and more costly storms (UN-IPCC, 2022. First Street Foundation, 2022). The increased likelihood and severity of flooding, and the growing cost of its damage, is one of the most destructive impacts of

climate change on communities and real estate. Coastal cities and communities at low elevations, such as Miami, New Orleans, and Houston, face the most severe risks from sea level rise and extreme precipitation events in the United States (NCA, 2018. First Street Foundation, 2022. FEMA, 2021). A 2005 study of environmental impacts on real estate in Carteret County, North Carolina, using a hedonic model to determine the factors of real estate value, found that "average property values are 5–10% lower if located within a flood zone" (Bin and Kruse, 2005). This study also pointed to the important fact that populations are growing in coastal zones at more than double the national rate, leading to strong growth in the value of coastal properties over time (Bin and Kruse, 2005). A 5-10% lower valuation due to location in a flood zone shows that current real estate values can sometimes take into account current environmental risk ratings, however, this does not mean current prices reflect the projected changes in environmental risk. Other studies, from the United States and abroad, have found little or no statistical relationship between flood risk and real estate value using a variety of models (Cupal, 2014. Bin and Kruse, 2005).

Not only are coastal cities and communities at risk, but also the communities that are located within river floodplains (IPCC, 2022). Many inland states, including West Virginia and Kentucky, face extreme flood risks that are made worse by the less predictable precipitation patterns brought on by environmental change (IPCC, 2022. First Street Foundation, 2021. NCA, 2017). While the topic of inland riverine flooding receives less attention in academia and the media than coastal flooding, it is an equally important risk for real estate stakeholders to consider.

Even a small amount of flood water can cause costly damage to property by way of direct water damage and mold, losses of critical systems and utilities, and result in higher operations costs due to higher insurance premiums and repair costs. The impacts of flood events on real estate value were hedonically modeled in 2017, and again in 2019 by a team from Cornell University, which found that;

“While the empirical evidence on the pricing of flood risk exposure in residential real estate held by uninformed households is mixed, this study shows that sophisticated investors in commercial real estate markets rationally respond to heightened flood risk by bidding down the prices of exposed assets. Using a detailed property-level database on commercial real estate transactions completed in New York, Boston, and Chicago before and after the shift in the salience of food risk caused by Hurricane Sandy, we document that properties exposed to flood risk experience slower price appreciation after the storm than equivalent unexposed properties. We further show that: the price effect is not driven by physical damage incurred from Hurricane Sandy, nor by concurrent unrelated pricing trends for waterfront property; it persists through time, suggesting it does not reflect a temporary overreaction that is subsequently reversed; it is driven by higher risk premiums for exposed properties; and it is exacerbated by contagion from locally important occupiers.” (Cupal, 2014).

There is statistical evidence that high flood risk leads to slower price appreciation after a major storm, and the slower depreciation does not subside over time (Cupal, 2014). This finding along with other similar analyses proves that environmental change is already impacting the value of real estate.

A 2018 report on US real estate and flood risk from the Union of Concerned Scientists found that,

“more than 300,000 of today's coastal homes, with a collective market value of about \$117.5 billion today, are at risk of chronic inundation in 2045, a timeframe that falls within the lifespan of a 30-year mortgage issued today. Approximately 14,000

coastal commercial properties, currently assessed at a value of roughly \$18.5 billion, will also be exposed to severe flood risk during that time frame” (UCS, 2018).

The UCS study focused on the effects of sea level rise on residential real estate, comparing the potential impacts of several global warming and sea level rise scenarios (UCS, 2018). These sea level rise risk estimates for total value-at-risk in the United States do not take into account inland river flood risk, the damages to infrastructure, the economy, and government services that can lead to significantly more value depreciation than from water damage attributed to sea level rise alone.

Sea level rise, increased storm severity, and the increased prevalence of floods, all worsening symptoms of environmental change, represent a catastrophic risk to certain markets, especially low-elevation areas along the Atlantic and Gulf coasts and properties already located within FEMA's 100-year floodplain modeling (UCS, 2018. First Street Foundation, 2021). The density of the flood risk in certain real estate markets across the country is on a scale that could lead to local systematic risks to the macroeconomy within the next 30 years, and of a type that could lead to a national real estate-financial crisis (UCS, 2018. First Street Foundation, 2022). A recent study published in 2023 in Nature Climate Change found that “residential properties exposed to flood risk are overvalued by US\$121–US\$237 billion, depending on the discount rate” (Gourevitch, et al., 2023).

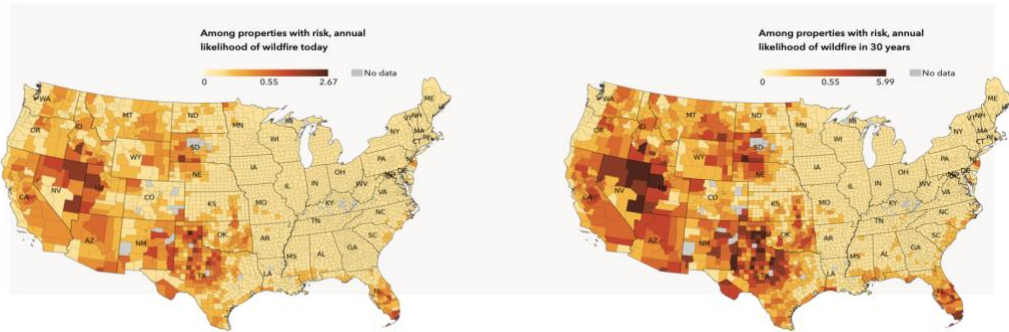
Wildfire Risk to Real Estate

As global temperatures continue to increase, and droughts become more common, the communities that have experienced a history of wildfires will see an increase in the

severity of fires, and the acres of land at risk of burning grows by the year (UN-IPCC, 2022. Miranda, et. al, 2015). Large wildfires are already burning millions of acres of land per year across the American West, with many buildings also caught in the path, leading to consequences for people's health, quality of life, and economic security in the most affected areas (NCA, 2017. Miranda, et. al., 2015. Solnit, 2009).

In 2022, the First Street Foundation released a first-of-its-kind national property fire risk report in the US, following up on their groundbreaking report on flooding and US real estate (First Street Foundation, 2022). The wildfire risk model grades property-level resilience at the parcel level across the US. This report allows consumers to access the "first free source of high-quality probabilistic wildfire risk information at the property level" (First Street Foundation, 2022). Up until 2022, calculating property-level risks took analytical and software skills, and time. Now, all individuals and businesses need is internet access to find out the environmental change risks of every property in the US, through FEMA, First Street Foundation, and other quality, free information sources. This means that renters, homebuyers, investors, and governments can begin to factor future environmental risk projections into their current investment decisions. The '*Risk Factor*' tool from the First Street Foundation gives investors the property-level, environmental risk projections that are needed to make informed decisions regarding long-term profitability and resilience (First Street Foundation, 2022). This environmental change risk analysis tool, and others like it, will inform consumers, lenders, developers, and investors, pushing the market to incorporate environmental risk projections in property valuation, which is generally not done today.

Figure 1: National Fire Risk Map (First Street Foundation, 2022)



County-level fire risk Map of the United States, based on property-level risk data, from the First Street Foundation (First Street Foundation, 2022).

A study conducted by First Street Foundation found that over 50% of residential real estate in the United States, or about 80 million properties face some significant-level of risk from wildfire, while 7% of property were characterized as being at *Extreme*, *Severe*, or *Major* risk of wildfire damage in 2021 (FSF, 2021). These risks are concentrated in the western half of the US, with only minimal projected wildfire risks for most of the eastern states. Almost 30% of all homes in the American West face *Major*, *Severe*, or *Extreme* fire risk over the next 30 years (First Street Foundation, 2022).

Like flooding, wildfires can destroy a single building or an entire community of buildings very quickly, while also wreaking havoc on infrastructure and natural systems. Those facing extreme wildfire risks in their area should take action to reduce those risks, including buying insurance, moving to a lower-risk area, managing local forest floor cover, or constructing homes/buildings with flame-retardant materials for property-level wildfire resilience.

There are several similarities between flood risk and wildfire risk in that they can both be catastrophic, hit the same areas repeatedly, and insurance will often pay for a home to be rebuilt in the same places with the same materials. While traditional homeowners insurance does not cover many types of flood damage, wildfire damage is generally covered under standard policies (Mockrin, 2015). Homeowners generally do not need to purchase separate fire insurance beyond their standard home insurance policy, leading to a large insurance premium pool that brings down the costs for individuals, but also leads to more policies with inaccurate risk premiums and homeowners paying more each year regardless of their on-site risks (Mockrin, 2015. Brenkert, et al. 2005).

To lower the risk to a community after a disaster, homes that are destroyed should not be rebuilt on the same site. Instead those funds could be used to build a home on a more resilient piece of land. A managed and incentivized retreat out of the most high-risk wildfire areas can be one of the most cost-effective ways for communities to build long-term resilience, with each home moved out of harm's way representing one less family to save or bail-out during and after a wildfire crisis (Miranda, et al., 2015). A study of a wildfire event in Boulder, Colorado in 2010 found that after a major fire destroyed over 150 homes, only 30% had been rebuilt 3.5 years later (Mockrin, 2015). For a small community, losing over 100 homes can be a major hit to the local tax base, and thus government services, putting the community at even higher risk from environmental change impacts. This report also found that communities were far more accepting of resilience policies and government spending immediately after the crisis (Mockrin, 2015).

There are resilience solutions at the property level to adapt to wildfires, as well as forest management solutions at the community/city/state level, however for certain communities facing extreme risk to a majority of inhabitants, the long-term economic outlook is very bad and the only logical solution appears to be a full retreat. Building with fireproof materials, reducing dried brush around a structure or in the forest, or managing a retreat away from the highest risk locations with property buyouts, demolitions, and zoning can improve resilience for those individuals and businesses at high risk of wildfire, and the surrounding community. There are limits to the effectiveness of all resilience solutions at the property or local levels, and certain locations will cease to be able to support human habitation in the 21st century.

Freshwater and Drought

Freshwater is necessary for all humans to survive, and even more freshwater is needed to maintain agricultural yields and energy supply. Due to the necessity of freshwater for all aspects of human society to function, it can be assumed that the availability of freshwater can impact real estate values. How much value is there in a city or individual piece of land if you cannot survive on it, can't grow food, and can't generate electricity without expensive adaptations? Freshwater is not unlimited; it comes in finite quantities and is spread unevenly across the states, leading to both risk and opportunity (Fishman, 2012).

Members of highly developed societies, and especially Americans, often think of water as an infinite resource, but while there is abundant saltwater on earth, there exists

only a comparatively minuscule amount of accessible freshwater. Limited freshwater resources are already being fought over around the globe, and due to environmental degradation from human activities and environmental change, those resources are becoming more limited each year. Global warming means more evaporation of surface water, as well as stormwater flooding that can spoil freshwater resources. For coastal areas facing sea level rise, as the saltwater encroaches on the land it can turn freshwater resources into unusable brackish water. Pollution of freshwater resources arising from human uses, such as in agriculture, power generation, and manufacturing further limits our nation's freshwater resources. Polluted discharge from these operations is generally sent into rivers, lakes, and groundwater with limited treatment and oversight. This causes algae blooms and other forms of freshwater degradation.

Freshwater can often represent a tragic case of the tragedy of the commons, for when there is a finite public resource, private individuals and corporations are incentivized to maximize their utility from that resource (Fishman, 2012. Reisner, 1986). Individuals, corporations, and governments often pull as much water from the ground, as quickly as they can, to facilitate profit-making enterprises, before the resource is exhausted (Fishman, 2012. Reisner, 1986). Those with the most financial resources to begin with are most able to take advantage of a common resource and exploit it through superior capital expenditure.

Many cities and towns are already experiencing the difficulty of extremely limited freshwater resources, especially in the southwestern United States (NCA, 2017. Fishman, 2012). In many parts of the Southwest, limits on the extraction of groundwater and water

budgeting policies have been implemented to try to preserve the resource for years to come, although the effectiveness of these programs to maintain current quality of life and economic output is unclear (Fishman, 2012. Reisner, 1986. Kearney, et al., 2014). The reliable supply of clean, accessible freshwater is shrinking for communities across the country, and the demand for freshwater is increasing with the growth in population, agriculture, and economy (NCA, 2018. Fishman, 2012). While humans have proven their ability to survive in desert locations around the world, losing access to freshwater makes life a lot more difficult, and leads to the correspondent issues of crop failure, famine, economic instability, and political instability that can have tremendous impacts on the value of property (Kearney et al., 2014. UN-IPCC, 2022). The solutions to water scarcity are limited in effectiveness for locations where too many people are living resource-intensive lives without the water resources to support that level of development and population (Kearney et al. 2014). Locations without reliable access to freshwater in 2023 have little hope for long-term economic success given the need for freshwater to support a stable society and economy, and the political difficulties and cost of moving large amounts of water over distances to keep a thirsty city alive.

In locations with freshwater scarcity, properties with rights to sustainable freshwater resources are more resilient in the era of environmental change, which leads to one of the resilient investment strategies that will be introduced and discussed subsequently in this paper. From a long-term perspective, the Midwest region's proximity to the largest above-ground freshwater resource in North America, its fertile soils, infrastructure, and links to Canada, make it an obvious target for real estate investors

seeking long-term resilience (Pogue, 2021. Kruegger, 2018. Shaw and Lustgarten, 2020. FEMA, 2021. NCA, 2018).

Other Environmental Risks

The warming of the earth – due to the exhaust of global industrialization – and its associated impacts on humanity, is only one piece of the environmental crisis. Humanity will also need to learn to live in a world with less biodiversity, depleted ecosystem services, increased pollution levels, fewer environmental sinks to dispose of our wastes, and dwindling critical resources such as quality topsoil, natural food sources, forests, clean freshwater, and fossil fuels (UN-IPCC, 2022).

The Inevitability of Further Environmental Change in 21st Century

Consider the scenario where humanity reaches net-zero carbon emissions this year and begins to reverse the impacts of global warming by sucking carbon dioxide out of the air and pumping it underground or some other method of storage after capture. A reduction in global emissions in 2023 will not show up in the reading of global temperatures and lived experience on the ground for many decades (UN-IPCC, 2022). Due to the distance between action and results, convincing Americans to drastically curb their emissions will be an extraordinarily difficult task. Many Americans don't believe in human-caused climate change – possibly because it conflicts with their worldview or due to an aversion to the institutions that produce the scientific research on the topic – and many American politicians are paid in campaign donations and other benefits to mislead their constituents about the risks of environmental change by that same companies who

rely on systems that cause environmental changes. There are also those Americans who believe in human-caused climate change but believe in a future technology that will save us, or the decision-making of deeply self-interested politicians will save us, or there are huge inaccuracies in the math of thousands of competing scientists and we will be okay. These are all ignoring the reality of environmental change in the present and near-term future that can not be avoided and must be adapted to.

Global environmental change – global warming, resource limits, natural disasters, etc. – represents a fundamental crisis to humanity, requiring us to evaluate where we live and how we live to protect ourselves, our families, and our communities, and in doing so improve the resilience of our nation and humanity (Bendell, 2018. IPCC, 2022). The question of global warming and its solutions are not the focus of this paper, and regardless of whether the impacts of the climate change crisis are to be successfully reduced through greenhouse gas emission mitigation by 2050 Americans will continue to need to adapt to environmental change in real time to survive and protect their families and assets in the 21st century.

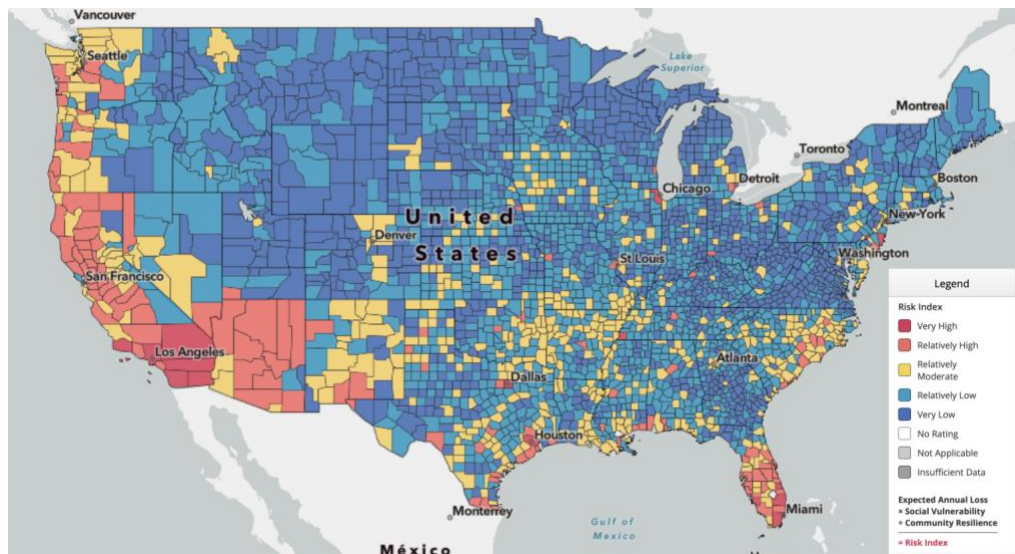
Spatially Diverse Risk and Mapping Risk and Resilience

The scale and scope of the impacts of environmental change are spatially diverse: individuals, communities, cities, states, regions, and nations will experience environmental change in different ways. Certain locations in the United States will experience environmental changes leading to economic losses, while other locations may benefit from environmental change. The environmental resilience of an individual,

property, or community is a function of both the expected environmental changes and the ability to adapt. The previous section introduced a few of the many environmental change impacts that will put downward pressure on real estate value, while this section will introduce the spatial disparities of those impacts across the United States. The two maps below will begin to show a picture of two Americas – one of vulnerable locations and another of resilient locations – clustered in specific regions.

The FEMA National Risk Index (county-level) is a composite metric of three factors: ‘Expected Annual Loss’, measuring expected losses in GDP from environmental impacts; ‘Social Vulnerability’, measuring the percentage of people who are minorities or live in poverty within an area; and ‘Community Resilience’, a composite rating of the ability of a community to respond to disasters, called the ‘Baseline Resilience Indicator’ (FEMA 2021).

Figure 2. National Risk Index Map (FEMA, 2021)



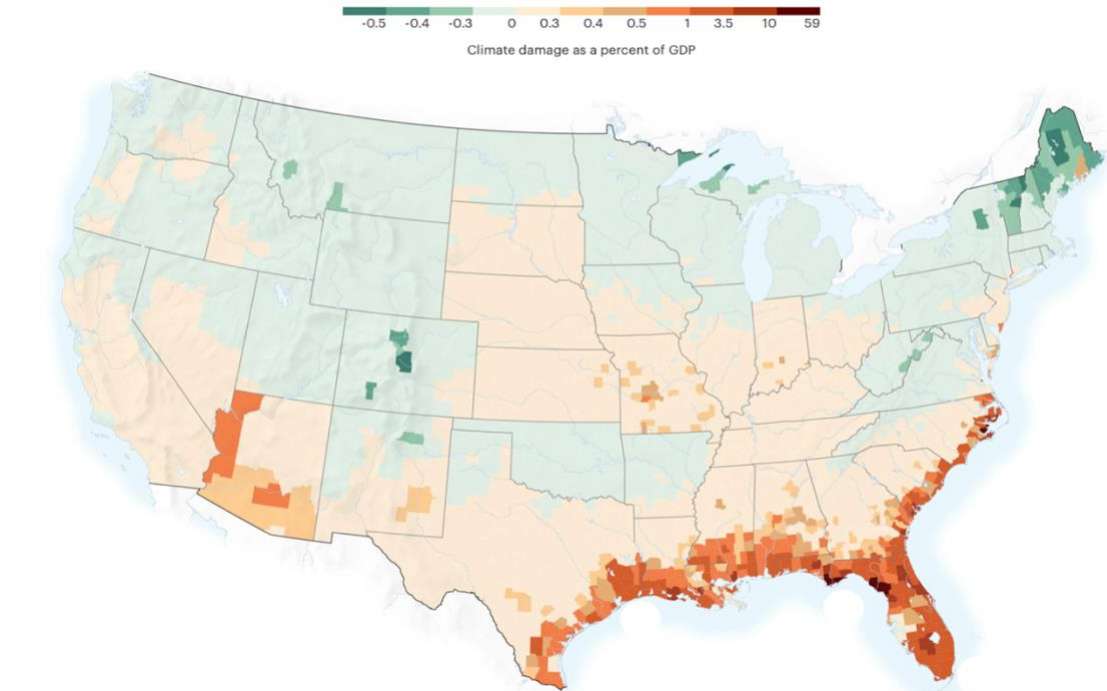
The National Natural Hazard Risk Index, a county-level resilience rating map produced by the Federal Emergency Management Agency. FEMA, (2021).

From the FEMA National Risk Index map, we can identify a clear trend of resilient locations being concentrated in the northern US away from the coasts, with the most resilient locations located primarily in the Northern Plains, Midwest, and Northeast states. Florida, California, and New Mexico immediately pop out as states where the majority of counties are graded as facing ‘severe’ or ‘extreme’ risk from environmental threats. The southern states have pockets of resilient counties surrounded by risk, while the northern states have a few risky counties surrounded by resilient ones.

The next map focuses on the projected economic damage from climate change, also at the county level. As contrasted with the National Risk Index, which grades short-term environmental risks by county, the map below, produced by the Rhodium Group and Propublica, projects economic damage by county in the period of 2040-2060 (Shaw and Lustgarten, 2020). This rating model leverages five factors (heat, wet-bulb temperature, farm crop yields, sea level rise, and very large fires) to model the risk of future economic damage as a result of environmental change.

“Rising energy costs, lower labor productivity, poor crop yields, and increasing crime are among the climate-driven elements that will increasingly drag on the U.S. economy, eventually taking a financial toll that exceeds that from the COVID-19 pandemic in some regions. Rhodium measured how much damage — or how much of a benefit — those counties might see, as a share of their GDP.” (Shaw and Lustgarten, 2020. Rhodium Group)

**Figure 3. Projected Economic Damage from Climate Change between 2040-2060.
(Shaw and Lustgarten, 2021)**



A projection of economic damage as a percent of GDP between 2040-2060 for each county in the United States, mapped by Shaw and Lustgarten in association with the New York Times and ProPublica (Shaw and Lustgarten, 2021). The locations in dark red are the most vulnerable locations in the United States, and the areas in dark green are the most resilient to environmental change.

The map above shows a major concentration of vulnerability along the Gulf Coast and southern-Atlantic coast. Both maps show a general trend of higher risk in the south and lower risk in the north, with Midwest, Northern Plains, and inland Northeast appearing to be the most resilient, and the coastal Southeast and dry Southwest as the most vulnerable regions in the United States. Florida, Mississippi, North Carolina, South Carolina, Louisiana, Texas, and New Mexico have multiple counties with climate damage as a percent of GDP above 3.5% per year (Shaw and Lustgarten, 2020. Rhodium Group). This projected impact on GDP, along with the migration and investment changes

that would accompany it, could put significant downward pressure on values within a twenty-year timeline, well within the term of a traditional 30-year mortgage. These two metrics of risk and resilience, and the risks outlined above, should make any real estate owner question the economic sense of holding long-term assets in the highest-risk locations identified in the maps above.

Real Estate Value: Land Rents, Market Value, Income Capitalization, and Climate Change

To understand the impacts of climate change on real estate value, we must first understand how the value of real estate is determined in both a theoretical context and a market-based one. The value, or expected transaction price, of real estate is determined by many factors including its location and asset quality compared to properties within the same market (city) or submarket (neighborhood), the rents and profits it produces (profitability), and the cost of reproducing the structure (reproduction cost) (Pagourtzi, et al., 2003). Each of these determining factors can be impacted by environmental change (Clayton et al, 2020).

To discuss the topic of climate change impacting the value of real estate, we must first consider why a piece of land has value. Why does the land itself, or a piece of dirt, have value? After outlining why a piece of land has value, I will explain how the value or market price of a piece of land or real estate is determined in a modern economic context.

Why does land have value? Literature Review on Land Rents theory

Three centuries of economic research has determined that a piece of land has value due to two primary characteristics: the tenant rent potential and the distance to a

central market (Von Thunen, 1826. Roberts and Woods, 2011. Fujita, Krugman, and Venables, 2001). The productivity of a piece of land can be measured in a few ways, with the classic model incorporating farmers 'bid-rents', or the maximum amount a farmer can pay the land owner while growing crops and selling them with enough of a profit margin to survive (Roberts and Woods, 2011. Fujita, Krugman, and Venables, 2001). In the earliest days of national-economic thinking in the 17th and 18th centuries, in the days of Adam Smith and Von Thunen, the utility value of a piece of land was determined primarily by its environmental factors, such as soil quality and hydrology patterns. Throughout history, economists have worked to develop models for predicting the value of real estate, with early efforts focused on the agricultural productivity of a piece of land and the distance to market in determining transport costs (Roberts and Woods, 2011). The original agriculture model is valuable because of its simplicity: the rent that determines the value of land is determined by the productivity of the land, the cost of doing business for the farmer (seeds, equipment), and transport costs (getting the goods to market), leading to a maximum amount that a farmer can survive in life and business at that price, also known as the 'bid rent' (Wood and Roberts, 2011. Fujita, Krugman, and Venables, 2001).

In the classic models of land rents and location theory, the best quality land near a central town has the highest value, while land that is of lower quality or further from the central town market is valued lower due to transport costs to the market (Von Thunen, 1826). The value of a piece of land, or its market trading price, has historically been determined by investors in the same way as it is today, by the rent it can command. A

piece of land with a more productive environment for crop growth could command a higher price than a comparable property that has less productive soils, and property closer to the central market could command higher prices due to lower transport costs of tenant farmers or businesses (Von Thunen, 1826). Following the industrial revolution and the rush of agrarian workers to manufacturing centers in cities, the classic land value model was adapted to a model less focused on land agriculture productivity (Fujita, Krugman, Venables, 2001). The theory that the most valuable land is located near the market, or urban core, and the least valuable land is located in the periphery, was first described in Western economic theory in 1826 by Von Thunen, but the idea has likely been considered by real estate investors and governments for thousands of years (Von Thunen, 1826. Fujita, Krugman and Venables, 2001. Winchester, 2021). This theory accurately describes the spatial value distribution within a given real estate market today, where the properties near the core are generally the most valuable and the properties furthest away have the least value (Woods and Roberts, 2011).

With the onset of the industrial revolution economic theorists moved away from the classic agricultural-based models towards a valuation model more equipped for the age of centralized factories (Wood and Roberts, 2011. Fujita et al., 2001). The value of land was determined less by its inherent environmental conditions (rainfall and soil composition) and more by its distance to an industrial base or market, based on the rent that could be afforded by a city factory worker, or today more likely a city office worker (Wood and Roberts, 2011. Fujita et al., 2001). The further development of the cities and shift towards a service economy, has led to real estate value being further determined by

its proximity to a major city (representing an industrial/service hub). The factor of agricultural productivity is replaced in the modern context by its rent-productivity, no longer determined by crop yields, but instead by how much an individual or business is willing to pay to live or work in a certain location. In the modern service economy, the greatest determinant of real estate value is its location in proximity to the urban core of a city, along with more nuanced factors of quality of life and economic opportunity in those areas.

The agglomeration of industries has led to the further skewing of value for land around specific industry hub locations. Locations with extreme concentrations of specific industries that can maximize economies of scale and network benefits have experienced rapid growth in real estate value (e.g. Wall Street and Silicon Valley) (Fujita, et al., 2001). The concentration of office and retail sectors in downtown districts leads to different patterns in the value of land and also the economics of housing around those locations. The pattern of agglomeration further complicates the model of assessing or predicting the transaction value of land today and going forward. It is not clear where the industries of the future will agglomerate. The value of housing relies on the demand and supply for it, and demand is driven primarily by jobs. If there are relatively good job opportunities in an area, real estate in that area is likely to be more expensive than where jobs are limited because workers pay rent in relation to their income.

The traditional models of land rents seek to determine the inherent value of real estate in a simplified way to draw conclusions about economics and markets, but not to accurately predict the value of an individual property. The theoretical simplifications

leave out important factors for determining real estate value in a modern context, such as quality of life factors in a particular area. Quality of life (environment, education, services) is an extremely important characteristic when considering the value of marketable property in a modern context. Consider why a home that is closer to the core of a city may be less valuable than a property of identical size and construction quality as a suburb that may be 10 miles from the core. Adam Smith, in his famous work, *The Wealth of Nations*, states that "every improvement in the circumstances of the society tends either directly or indirectly to raise the real rent of land, to increase the real wealth of the landlord" (Smith, 1776). This highlights the reality that many more factors go into the value of land than simply its proximity to a market and its production capacity, as the classic models of land value describe. The theory of agglomeration could be applied to the topic of resilient real estate, in that property vulnerability is clustered due to the spatially unequal nature of environmental impacts and the local market dependencies of real estate value. Resilient locations are likely to attract migrants and capital in the era of environmental change and see stability or growth in property values, while real estate in vulnerable locations that cannot adapt is likely to be devalued (Pogue, 2021. Sheldon, 2017. Clayton et al, 2021. Krueger, 2018. Shaw and Lustgarten, 2020). The literature review to follow will explain how the market value of a property is determined by current real estate decision-makers, which is critical for understanding how climate change can impact the value of real estate, and for understanding the approach to resilient real estate investment in the later sections.

Supply and Demand Forces and Resilient Real Estate

As the impacts of environmental change further erode the land and quality of life of millions of acres and Americans, the supply of resilient land is decreasing as the demand for it is increasing due to the growth in population and economic output of the United States (Pogue, 2021. Winchester, 2021). The value of real estate is impacted by the classic market forces of supply and demand, with landlords and developers as the suppliers of the space for living and working, and with individuals and businesses demanding that space to live and work. Besides population growth/decline and economic growth/decline, many other factors impact the supply and demand for real estate. Demographic changes, agglomeration, employer policy changes/layoffs, school quality, healthcare quality, major institutions such as state governments, large universities, and military bases can impact the demand for property in a location, as well as chronic environmental change and acute natural disasters that are beginning to impact demand for high-risk property (Clayton, et al. 2021. Cupal, 2015. Bin and Kruse, 2006). The cost of land, the cost of construction (including labor and material, architectural and engineering plans, environmental reviews, financing, and other costs), the rate of new construction, zoning, and building codes, all impact the supply of real estate. Acute natural disasters and chronic environmental risks can also impact the supply of real estate by eroding land, destroying homes, driving up the cost to borrow and insure, and thus driving up the cost to build in a multitude of ways (Clayton et al, 2021. Boland et al, 2021. USGBC, 2021). As the environment changes, the supply of resilient land will continue to fall, and the

demand for resilient land will rise as the projected impacts of climate change become further incorporated into current real estate valuations and consumer decision-making.

The Value of Rights Associated with Real Estate Ownership

The value of real estate encompasses not only the land and built structure, but also the rights associated with property ownership in the United States. Known within the industry as the Bundle of Rights, these include the rights of possession, control, exclusion, enjoyment, and disposition (Poorvu and Cruikshank, 1999. Pagourtzi et al, 2003). There is an extensive body of law related to property and the legal rights attached to real estate ownership, but the basic principles are that an owner of real estate can do what they want with their property (within the bounds of local zoning and public policy), control who is allowed on their private property (without discriminating, if it is an income property), and transfer the property as they see fit, all without unreasonable interference from the government.

In practice, all of these rights are limited by the government to different degrees depending on the state, with important implications for projecting the economic changes of climate change impacts, policy solutions, and investments. The government has the right to take land from private individuals for public benefit and is required to pay a 'fair' price for it, in a process known widely as eminent domain (Lovett, 2016). The rights of property owners are and always have been limited by the government for the benefit of society, with major implications for the value of the property (Winchester, 2021). For investors and developers, the specific local zoning laws and building codes defining what can and cannot be built on a property have enormous implications for value. Changes in

these laws have major implications for the market, by changing the rights of property owners, and thus changing the value of properties within that jurisdiction of zoning and/or building codes (Coaffee and Lee, 2016). Zoning laws that allow the local government to determine where and what property owners within their jurisdiction are allowed to build, and the government's right to take your land – through eminent domain – are two of the strongest tools governments have available to propel resilient decision-making in order to protect individuals and markets in the United States (Coaffee and Lee, 2016).

The effects of zoning on real estate value and resilience vary depending on the investment strategy, since zoning rules can preserve value by restricting the supply of housing due to the limits on density (lower supply leads to higher prices), or it can also be a primary factor in the value of a property if the owner is allowed to develop something more profitable than the current use (Poorvu and Cruikshank, 1999. Winchester, 2021). Developers can make their entire careers on the zoning and development potential of a single rare property that has been missed by the rest of the market (Poorvu and Cruikshank, 1999). Inside information is not only permitted in the real estate industry, it is a standard of the real estate market and often the key to understanding a transaction price, especially on large trades (Poorvue and Cruikshank, 1999. Winchester, 2021). Due to the individuality of property, its non-fungibility, and the stability of its place in space through time, each property's value is determined imperfectly, with far more limited information than what is available to investors in public equity or debt markets where a greater level of transparency is required by law. For example, two individuals with long

careers determining the value of a property as appraisers or assessors for a mortgage lender or tax jurisdiction, are more likely than not to determine different predicted market transaction prices for the same property. The exact market value can only truly be determined when a market buyer is found and an agreeable price is determined and closed on. For investors, this means that market research and due diligence are crucial before any investment decisions are made, and this is even more so the case in resilient real estate investment decisions (Clayton, et al., 2021).

Based on this short review of the historical and modern literature relating to real estate valuation, it becomes clear that real estate value is determined by a combination of its location and productivity in terms of rents, with transaction prices further explained by a multitude of supply and demand factors that impact a potential buyer's willingness to pay. Only some of these factors can be quantified accurately in a model. It is important to consider that the perceptions about a location can impact the value of the property even if those perceptions are unsupported by reality. For example, consider a hypothetical vulnerable location where the current perception is that the local real estate market will continue growing in population and economic output indefinitely with a stable environment. Consider if new information became available, perhaps after a disaster, and perceptions changed as to the long term outlook of the location. Changing perceptions about resource limits or other environmental changes can have significant impacts on the value of property, potentially even before physical risks of environmental change are experienced locally.

Literature Review of Methods for Determining Property Market Value

The market value of real estate is traditionally determined in one of three ways: the income approach, the reproduction cost approach, and the comparable property/market analysis approach (Pagourtzi, 2003). The income approach is the most common for commercial properties, often called investment properties, which include multifamily properties, offices, hotels, industrial, retail, and any type of real estate that is not considered residential (1-4 residential units at a single property) (Pagourtzi, 2003). For a single-family home or condo property, the most common valuation method is the comparable sales and market analysis approach, comparing the asset to recent sales in the area to project a likely transaction value (Pagourtzi, 2003). Based on this approach, if homes in an area are selling for less than a couple of years ago (due to any factor) then the subject property's transaction price is expected to be lower than it would have been a couple of years before (Pagourtzi, 2003). If that decline in sales prices is due to environmental risk, then a property with comparably strong site-level resilience might retain its value for longer than a comparably vulnerable property, which is the general concept of locally-resilient property that will be explained further later in this section.

The market value of a home can also be estimated using the reproduction cost, or the cost of rebuilding an asset of the same quality (Pagourtzi, 2002). The reproduction cost approach and the income capitalization approach require a level of information and contain enough complexity that they are usually ignored by the average homeowner or real estate agent in the valuation of real estate, in favor of a classic market analysis/comparable-sales approach.

Income-producing properties, such as multifamily buildings, retail strips, or offices are most often valued by a function of the income they produce, known as the income capitalization method of valuation or appraisal (Pagourtzi, et al. 2002). The basic formula for calculating a property's current value based on its future profit potential is net operating income (NOI) divided by market value equals the capitalization rate. The net operating income is the collected rental income plus other property income (such as laundry and utility reimbursement), minus the total operating expenses (e.g. real estate taxes, insurance, repairs and maintenance/management fees/marketing, etc). Operating expenses do not include mortgage payments (cost of capital) or capital expenditures (capital improvements). The 'cap rate', as it is known, generally holds steady for a specific property type and quality in a specific location, and those with an accurate estimate of a location's cap rate (given the asset type and quality) can easily determine the potential transaction value of any property with only its NOI (Pagourtzi, 2003). This is a simple method, but it is the primary baseline for the valuation of income-producing properties. The results of the income capitalization valuation are often compared to the results of a market/sales-comparison approach, and the reproduction cost estimate if it is available.

The income potential of a commercial property is the crucial determinant of its value, similar to a company. If the income of a property goes down, or its expenses go up, this change in income potential will lower the property's value. Real estate taxes and insurance can often be the largest operating expenses for owners of income-producing

properties while other significant costs include utilities (tenants often pay for some or most utilities), repairs and maintenance, and management costs.

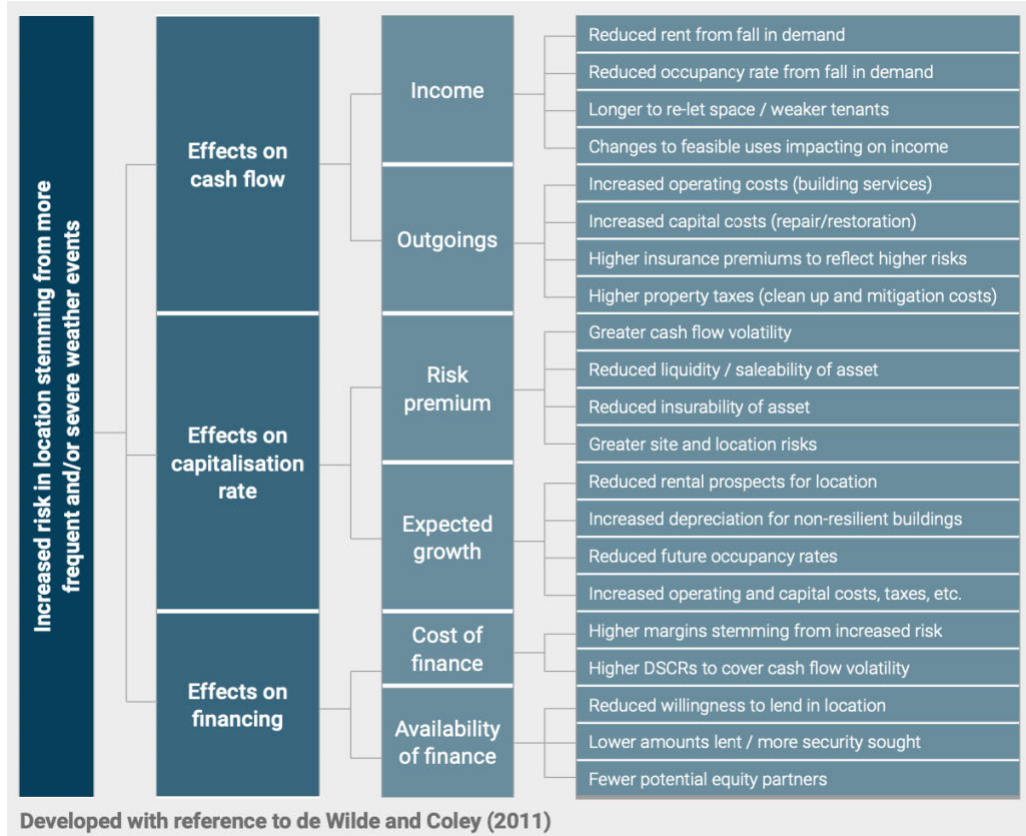
Other valuation methods include more intricate math and data tools to build more accurate models of real estate value. An example of this is multiple linear regression, which can be used to build a model that attributes value to the different factors that impact the value, such as size, bedroom count, bathroom count, and distance from downtown. This sort of model can be used to identify the value of a property that can be attributed to certain characteristics related to environmental change.

Resilient real estate investment decisions must consider not only the current profitability and market value, but also the future value, without perfect information in the present, and especially not for the future.

Income Capitalization: How Environmental Change Can Impact the Value and Profitability of Commercial Real Estate

To understand the concept of resilient real estate it is important to understand the many different ways that environmental change can impact the valuation of property. This section will primarily focus on the impacts of environmental change on the income and expenses of an income-producing property, whether that be a large multi-family building or another commercial real estate type.

Figure 4. Impacts of Climate Risk on Real Estate Asset Performance (Clayton, 2021 referencing Wilde and Coley, 2011)



This chart, created by Jim Clayton in 2021, referencing a 2011 paper by Wilde and Coley, details the impacts of extreme weather on real estate value, in terms of impacts on cash flows and capitalization rates, as well as impacts on financing. Extreme weather events lead to less income, higher costs, higher capitalization rates to reflect risks, and higher interest rates, all impacting the profitability of real estate assets (Clayton, 2021. Wilde and Coley, 2011).

Based on the information provided in the table above and the insights in the previous section, I have created the following table to display how environmental change can impact the income and expenses of a property. The estimated revenues and expense figures are unscientific estimates used for the sake of showing how small changes in

income and expense items and capital costs can have a significant impact on the valuation of real estate.

Table 1: The Effect of Environmental Risk on Profitability, Income, and Expenses

<i>Income and Expense Item Type</i>	<i>Dollar Amount</i>	<i>Percent of GPR</i>	<i>Environmental Change Impact on Income and Expenses in High-Risk Locations</i>	<i>Post-Environmental Change Dollar Amount</i>
INCOME			Environmental change can negatively impact the value of real estate by decreasing a property's potential rental income.	
Gross Potential Rent (GPR: annual revenue potential)	\$1,000,000	100%	Decreased demand and lower area rents for similar units leading to a lower GPR.	\$950,000
Vacancy (empty units)	(-) \$50,000	5-10%	Less demand leading to higher vacancy.	\$70,000
Bad Debt (unpaid rent)	(-) \$20,000	2%	More disasters and damage leading to more unpaid rent.	\$30,000
Concessions (giveaways)	(-) \$10,000	1%	Less demand leading to the need for more concessions to attract tenants.	\$15,000
Actual Rental Income	\$920,000	92%	Lower Actual Rental Income due to lower GPR and higher vacancy, bad debt, and concessions.	\$880,000
Other Income (Parking, Laundry, Utility Reimbursement)	(+) \$20,000	2%	Increased vacancy leads to lower other income collection for laundry, utility reimbursement, and parking.	\$16,000
Total Operating Revenue	\$940,000	94%	Total operating revenue is reduced by a decrease in GPR and other income collection,	\$896,000

			and an increase in vacancy, bad debt, and concessions.	
<i>OPERATING EXPENSES</i>			Environmental change can increase many of the expense line items, especially the largest items including real estate taxes and insurance, and repairs/maintenance.	
Real Estate Taxes	\$100,000	10-20%	Increase in taxes to make up for local government budget shortfalls due to current and projected environmental change.	\$120,000
Insurance	\$80,000	8-15%	Increase in insurance payments to accurately reflect risk.	\$120,000
Utilities (Electricity, Gas, Water-Sewer, etc)	\$60,000	5-10%	Increase in the cost of electricity, water, gas, oil, and trash removal due to environmental change.	\$70,000
Repairs and Maintenance	\$50,000	5-10%	Increase in R&M costs due to an increased rate of wear and tear on the property from changes in environmental conditions and tenant behavior.	\$70,000
Management Costs	\$40,000	3-5%	Increase in management costs to reflect operational complexities associated with high environmental risk.	\$50,000
Cleaning and Turnover	\$20,000	2%	Increase in cleaning and turnover costs to reflect worse environmental conditions and changing tenant behavior. Tenants are less likely to treat their units well if there are other issues at the property or if conditions degrade in the surrounding area.	\$25,000

Marketing	\$10,000	1%	An increase in marketing expenses to due to decreased demand and lower willingness to pay for renters in vulnerable areas.	\$20,000
Total Operating Expenses	\$350,000		An increase in total operating expenses, due to the direct impacts of environmental change leading to higher repair costs, along with changes in risk profile leading to higher insurance costs and special tax assessments to fund resilience.	\$475,000
Expense Ratio (Total Expenses / GPR or Income)	35%		Higher expense ratio due to lower revenues and increased costs.	50%
Net Operating Income (NOI = Total Income - Total Expenses)	\$590,000		Lower NOI due to lower rental income and higher expenses. NOI is a major determining factor for the valuation of real estate due to the income capitalization of future cash flows and the capitalization rate calculation of cap-rate = NOI / Value	\$475,000
Debt Service (Mortgage payments of Interest and Principal over the life of the loan)	\$300,000		The cost of capital increases to accurately reflect the changing risk profile of the subject property.	\$350,000
Property Income (after debt service, pre-Income tax, a.k.a Profits before Income Tax)	\$290,000		Climate change can lower total property income due to lower rents and higher expenses, and after-debt income can be further lowered by higher capital costs (higher interest rates to account for higher risk).	\$125,000
Capital	Example,		Planned and surprise capital	Example,

Expenditures (A capital expense not an operating expense)	\$200,000 for a major roof repair that was expected.		expenditures costs can increase due to unforeseen acute damage and long-term property resilience upgrades. Increased need for capital reserves to cover necessary capital expenditures can cut further into property profitability.	\$300,000 for a flood repair, on top of the \$200,000 necessary roof repair that was already planned.
Capitalization Rate	5%		The greater the risk the greater the necessary return to justify the investment, leading to a higher capitalization rate.	6%
Value	\$11,800,000		NOI / Cap Rate = Value. The difference in projected NOI and Cap Rate for the same property under changing environmental conditions can have an enormous impact on the value of a property.	\$7,916,667 (33% reduction in value after including severe environmental risk projections in cash flow valuation)

This table is meant to be used as a teaching example. The figures are not based on a specific property but with income and expense projections within the range of normality for a common large city multifamily property in the current real estate market. This table should not be used as cost guidance or investment advice, it is an example for teaching purposes to inform individuals on the dramatic potential impacts of environmental change on the value of US real estate. The environmental impact notes on each income and expense item were informed by Clayton, 2021 and Wilde and Coley, 2011.

From this income capitalization example, it is clear that environmental change can negatively impact the income and expenses of a property leading to a lower property valuation. In a traditional income capitalization analysis, each of these values would be projected forward over ten to thirty years to determine the present value of the future cash

flows a property can produce. This is similar to how most assets and securities are traditionally valued in the marketplace, by finding the net present value of the cash flows over a period of time. This sort of valuation is especially important in considerations for financing, where a lender will want to know how profitable the property is today to determine how much debt the asset can support. The bank wants to know what maximum monthly payment that can be made given the current and future profitability of an asset.

The income capitalization approach is the most common way to value a piece of income-producing real estate, such as multifamily, single-family home rentals, retail, office, hotels, and industrial space. Homes (including condos) are most often valued using an analysis of comparable sales (Supply and Demand), but an analysis of the potential rental income and hypothetical income capitalization is common as another measure of value.

Transition Risks vs. Physical Environmental Risks to Real Estate.

Real estate value is impacted by environmental change in two distinct but related ways; through physical risks, such as flooding or fire, and through transition risks, such as changes in demand and new regulations (Mckinsey & Company, 2022). Transition risks are those resulting from "changes in the economy, regulation, consumer behavior, technology, and other human responses to climate change", and can include increasing utility and insurance costs, fines for inefficiency, and changes in consumer demand for certain locations (Mckinsey & Company, Boland, et al., 2022. Sustainability improvements, or decarbonization, is one of the primary ways to mitigate transition risks,

however decarbonization will not protect the value of assets with extreme physical risks (Boland, et al., 2022).

“The combination of this economic transition and the physical risks of climate change has created a significant risk of mispricing real estate across markets and asset classes. For example, a major North American bank conducted analysis that found dozens of assets in its real-estate portfolio that would likely be exposed to significant devaluations within the next ten years due to factors including increased rates of flooding and job losses due to the climate transition. Additionally, a study of a diversified equity portfolio found that, absent mitigating actions, climate risks could reduce annual returns toward the end of the decade by as much as 40 percent.” (Mckinsey Company, Boland, et al., 2022).

Both transition risks and physical risks are likely to impact real estate valuations in the United States in the decades to come, leading to devaluations for vulnerable assets (Mckinsey Company, Boland, et al., 2022). Real estate decision-makers can use adaptation solutions, including many resource efficiency upgrades, to improve the resilience of their assets to the physical risks and transition risks associated with environmental change.

The Systemic Risks to Real Estate and the Macroeconomy: The next real estate-financial crisis?

The residential real estate market in the United States represents over \$36 trillion in total value (Richardson, 2021). For comparison, the US Federal Government budget in 2021 was under \$7 trillion in total (US Department of Treasury, 2021). The total

combined value of all residential real estate grew by almost \$7 trillion in 2021, during the Covid-19 pandemic (Manhertz, 2022).

Due to the scale and scope of environmental risk in the United States, and the importance of stable real estate value in the macroeconomic economy, the case can be made that environmental change in the 21st century will induce a real estate-financial crisis. In the years leading up to the 2008 financial crisis, the massive securitization of overvalued real estate assets into mortgage-backed securities along with the use of risky credit default swaps and other complex financial securities by interdependent institutions led to systematic risks going unnoticed by most (Shaxson, 2011). Individuals were investing in second homes, flipping homes as a second job, and getting bigger mortgages than they could handle, yes, but the unregulated greed on the part of major American business institutions to maximize profits and minimize public benefit was the dominant factor leading to the crisis (Shaxson, 2011). The finger can be pointed at many different groups, and there are arguments to support or defend all sides, with the banks, the regulators, the credit rating agencies, the insurance companies, the law firms, and accounting firms all playing their part in the systematic transfer of real estate benefits to major capital holders and costs and risk onto the government and taxpayer. For example, the credit rating agencies stamped junk-quality assets as high quality, based on guidance for lending/rating rules from Federal government institutions (Fox, 2013). The under-accounting for risk, in large part due to the complexity of securities that trade constantly between big banks, tying their success together, inevitably blew up the system. Lenders were not accurately assessing risks for individual mortgages (lending to people who

couldn't afford their debt payments, or to homes that should never have supported that level of debt), as well as for pooled mortgage-backed securities (MBS and CMBS) bought and sold by major financial institutions.

As real estate prices stopped rising and began to fall in 2007, and the real estate market cycle turned over, borrowers were defaulting on their loans at higher rates than expected, putting the mortgage-backed securities at risk of default as well (Fox, 2013. Crotty, 2009). The underassessment of risk, among the big banks and insurers, the government, and the individual, is what led to the fall of AIG and Lehman Brothers, and what would have pulled down more of the global financial system if not for the US federal government bailing out several major banks and other large US companies, and injecting capital into markets, in the Keynesian fashion (Fox, 2013. Crotty, 2009). Before that crisis, some were calling for reforms to the relaxed lending and secondary-mortgage market standards, as well as more regulation on mortgage-backed securities, credit-default swaps, and other complex financial securities created to diversify risk and maximize returns (Fox, 2013. Shaxson, 2011). Those voices of concern were not listened to by most market players, and it took a major financial crisis for the market to correct, if only slightly, by increasing regulations on banking and real estate lending as well as other safeguards into the system to prevent it from happening again (Dodd-Frank Law, US Congress, 2010). If the US hopes to prevent a similar real estate-induced recession as a result of climate change, it must act rapidly to build resilience and reform its financial system before it is torn apart from within. The risks are glaring, however, like in the

Great Recession, there are opportunities within this impending real estate-financial crisis, which will be discussed later in the paper.

In the United States, many of the most highly valued properties are located along the sea, in communities that may be completely inundated within thirty years. Consider that a traditional mortgage is thirty years long and that U.S. government-backed institutions buy many of those mortgages from banks on the secondary mortgage market, leading to an unsustainable financial burden of risk for the nation as a whole. As mentioned previously around 15% of all properties in the US are already at significant risk of flooding, with over five-million properties already facing 'extreme' flood risk (First Street Foundation, 2020).

In 2018 the Union of Concerned Scientists warned that one million homes in Florida may be chronically inundated by the end of this century, representing 10% of the total Florida housing stock, and including some of the most expensive and desirable properties in the state (Union of Concerned Scientists, 2018). 20-25% of Florida properties today are already at substantial risk from flooding (First Street Foundation, 2020).

Property taxes generally fund local governments, emergency services, and public schools. If real estate values fall, the local government's tax base shrinks, with repercussions for the whole community (UCS, 2018). When local governments are working to clean up from major disasters or build resilience, they will have to do it with a lower overall budget. The issue of local government funding is one reason why the

federal government is often needed to support local relief efforts with FEMA dollars. However, once the acute crisis subsides, and FEMA moves on to the next crisis, the local government will be left with a slashed budget and a community that needs rebuilding to continue life as before (UCS, 2018). In the projections of residential property at risk from flooding in Florida, the Union of Concerned Scientists predicted that many communities will face tax base reductions of over 20% along much of the coast and even 60% in certain locations like Miami (UCS, 2018). Losing 60% of the local tax base could be catastrophic to any locality without support from state and federal partners. In the case of Florida, the state is swamped with risk across its territory, and it is unlikely the state government will have enough funds to offset the flooding losses in every local community and city.

Florida is the prime example of a state with enormous environmental change risk to life and property, yet the state government is only beginning to address the existential threats it faces (Pogue, 2021). The consequences of further inaction are projected to be devastating for coastal residential and commercial properties in Florida: "by the end of the 21st century nearly 2.5 million residential and commercial properties, collectively valued at \$1.07 trillion will be at risk of chronic flooding" (Union of Concerned Scientists, 2018). The one-trillion-dollar price tag of potential damage is an eye-popping number for a single state, but it is also a relatively conservative estimate compared to other similar research that was done more recently by the First Street Foundation in 2021. The drastic costs of flood damage as a result of global warming and sea level rise will undoubtedly create tense situations between communities, businesses, and governments.

Who will pay for the cost of damage, rebuilding, devaluations, and tax base losses? Prior to 2008 and continuing on, major corporations and financial institutions have sought to avoid risk and liability as a part of their nature as profit driven enterprises, and most often prioritize short-term profits over long term social benefit considerations (Crotty, 2008). It is not clear whether the costs of under accounting for risk in property and financial markets will be paid for solely by Americans and the Federal Government or if corporations will share in the burden they helped create.

The current estimates for sea level rise by 2100 are between 0.6-2.2 meters under a moderate emissions reduction scenario (NOAA, 2022). The high end of that range would put the majority of south Florida properties underwater (First Street Foundation, 2021). Triaging, in terms of resilient investment, as well as managed retreat, will need to be considered to effectively and efficiently reduce national risks by focusing on locations where maladaptation is less likely (Carrey, 2020). Based on the research presented in this paper, investing in real estate in Florida, Arizona, Louisiana, and California today is an especially risky endeavor; however, developers and lenders looking for short-term gains can still make a strong profit, so capital is still flowing into many vulnerable locations at unsustainable rates. There is a widening mismatch between the incentives of people living or investing in these areas long-term, and the incentives of those looking to make a short-term profit. The developer or short-term lender won't care about anything that isn't affecting prices during the timeline of their investment. If a development project takes three years to complete, the developer is less likely to consider the long-term environmental risks than a home buyer or investor with a financial interest often lasting

beyond ten years. Attempting to explain to a condo developer why they should change their behavior because of the long-term risks for a property while their financial interests are on a three year timeline is often a futile conversation. Without intervention from government and industry groups, these dangerous incentive differences will likely continue until asset values and securities prices accurately reflect risks, either through the impacts of environmental change, or the regulations and spending to realign incentives and counter the environmental forces.

Generally, the US real estate market is not accurately incorporating future risks of climate change into pricing or mortgage finance considerations, however, certain specific areas have started to see demand-side internalization of climate risks in purchasing decisions (Kousky et al, 2020). There have been many studies done in recent years on the projected effects of climate change on coastal real estate values, and if changing trends can already be seen. Some of these studies have found that price effects can already be seen in areas facing very high sea level rise risk, such as Miami Beach, but for most of the country, prices have not fully incorporated climate risk (Keys and Mulder, 2020). The report found that prices were growing 15-20% slower in the period from 2013-2018 in areas of high risk along the Florida coast compared with areas of moderate risk (Keys and Mulder, 2020). This research is some of the first statistical evidence showing real estate prices being negatively impacted by environmental change in a major US real estate market. The researchers attributed the price changes to demand-side preferences, with Floridians internalizing the climate risks in their real estate purchasing decisions (Keys and Mulder, 2020). This reflection of risk first occurring on the demand side of the

market is worrying because governments and financial institutions have far more access to risk information than the average home buyer or builder, and are choosing to continue on a business-as-usual path. Without serious adaptation measures in real estate finance, flood insurance, and disaster response, the current real estate system faces grave risks.

For most homeowners in the US, their regular homeowner's insurance does not cover major damage from flooding, so homeowners who seek traditional mortgage financing are often required or encouraged to purchase insurance specifically for flooding (FEMA, 2015). The current national flood insurance system is funded by FEMA, the Federal Emergency Management Agency, which subsidizes flood insurance costs for homeowners in areas that are at risk of flooding by subsidizing plans sold and operated by private flood insurance companies (FEMA, 2015). When flooding from a major storm damages homes, homeowners look to their insurance policies for the money to rebuild in the same location. National Flood Insurance Program (NFIP) policies are sold and serviced by private insurers, with FEMA covering the claims (National Law Review, 2019). This represents a moral hazard, where private insurers are not incentivized to properly account for risk, as they do for every other insurance type, because they are not responsible for paying out the claims (NLR, 2019). Homeowners can get at most \$250,000 from the National Flood Insurance Program, and businesses as much as \$500,000 to rebuild in a location that has likely flooded in the past, and will again in the future (FEMA, 2015). While this payout may be enough for some owners, it is often not enough to cover the cost of major damage, and many homeowners who file claims never receive a check due to the limited budget and bureaucracy within FEMA to respond to

disasters. A study by the National Law Review in 2019 found that many NFIP claims were not paid out because of loophole exclusions in certain policies (such as the 'earth movement exclusion'), budget limitations at the federal level, and lack of documentation of damages (NLR, 2019). Private insurers can profit from policies that they do not pay out claims for, and are incentivized to minimize claims sent to the federal government, so individual homeowners are often left ruined, and taxpayers are again on the hook for uninsured damages (NLR, 2019).

FEMA flood maps are meant to show all properties that have at least a 1% chance of annual flooding, but until recently those maps were not accurate (NLR, 2019. FEMA, 2021). Before the recent overhaul of the FEMA flood maps and policies, millions of homes were at above a 1% chance of annual flooding but were not included in the 100-year floodplain maps (Keller, 2017). In 2020, the First National Flood Assessment, from the First Street Foundation, found that over 16 million homes were at risk of flooding (1% annual flood risk), while FEMA had only identified 8 million homes at that risk level (First Street Foundation, 2020). FEMA flood maps are used for finance and insurance considerations, putting the real estate system at risk due to environmental risks that are under accounted for.

The increasing cost of flood damage each year on American property is exposing the pressures that will squeeze the National Flood Insurance Program, potentially pushing the entity to the brink of collapse (Union of Concerned Scientists, 2018. First Street Foundation, 2020). The loss of the 'insurer of last resort' or 'lender of last resort', the US government, could be catastrophic to markets whose values are dependent on the ability

to finance and insure the property at a reasonable cost. Each year extreme precipitation events leave tens of thousands of Americans with a financial burden of flood damage in their homes (UCS, 2018). Even if a real estate owner has the resources to cover the damages from a storm, spending to rebuild or repair damaged homes will further expose the vulnerability of coastal property and the flood insurance system. If FEMA does not have the resources to cover those damages, or if their flood rating system continues to account for risk, many homeowners and borrowers holding flood insurance policies will be in dire straits as natural hazard risks increase (UCS, 2018).

In 2021, FEMA released its plans for its 'Risk Rating 2.0' program, a major overhaul of its rating system that goes beyond the basic considerations of flooding height and property elevation (FEMA, 2021). The new pricing methodology for policies is applied to all new policies and policy renewals and considers the cost to rebuild, structure elevation, distance to flood source, and flood risk type, among other factors (FEMA, 2021). The first phase began in 2021 and is now being fully implemented for all new and renewing NFIP policies (FEMA, 2021). Rate increases in high-risk areas are capped per year so there is no serious price shock from the Risk Rating 2.0 implementation. A FEMA study on the new program found that 96% of policy premiums will either decrease due to these changes, or minimally increase by less than \$20 per month (FEMA, 2021). As much as two thirds of policyholders are expected to see decreases in monthly premiums, while only a small subsection of properties will see their rates increase significantly over the coming years (FEMA, 2021). This is a good sign that FEMA and the Federal government are taking significant steps to reduce environmental risk by

making Americans with NFIP policies account more for environmental risks in their decision making. It is not clear that these changes will be enough to make the program resilient over the long-term. The federal government continues to provide NFIP policies in high risk locations, providing affordable flood insurance coverage to homes that would otherwise be uninsurable or be charged prohibitively high premiums, allowing Americans to continue to live in the most vulnerable locations affordably (FEMA, 2021. FEMA, 2015).

A similar moral hazard arises in the mortgage lending industry. When a bank lends a homeowner money to buy a house, the lender generally does not hold that debt asset on their balance sheet. Lenders will often sell that mortgage into the secondary mortgage market (including Fannie Mae and Freddie Mac) to recoup those funds through mortgage-backed securities markets, and lend it elsewhere while retaining the rights to profit off the servicing of the loan. The secondary mortgage market is made up of several major lending institutions that are backed by the federal government to drive down the cost of home ownership nationally. If the bank's profits were dependent on their principal getting repaid over 30 years (traditional residential mortgage length), they would be incentivized not to lend to homeowners buying in areas that will be underwater in 30 years. However, since the federal government is on the hook in the case of a default, the mortgage lenders will often not care as much if the principal gets paid, just that it meets the lending standards of Fannie Mae and Freddie Mac. Banks continue lend in areas they know are environmentally vulnerable because their incentives allow them to avoid most of the risk by selling those loans to secondary markets, putting the downside risk on the

shoulders of the federal government and taxpayers. Currently, these lending standards allow for the federal government to purchase mortgages backed by homes and buildings that are already at severe risk of flooding. Not only is the US federal government on the hook for paying out insurance claims to homeowners (through the NFIP), but it is often also a majority owner (debt owner) of those at-risk homes. And, the US government is the lender-of-last-resort and disaster manager of last resort, increasing the hazards even further.

If these current systems of our government and economy relating to real estate are not reformed, it could lead to the collapse of the flood insurance industry and more importantly, the mortgage industry in flood-prone areas. If homeowners can't buy flood insurance, it will be very difficult to get traditional mortgage financing. If potential buyers can't get traditional mortgage financing on coastal properties without paying prohibitively high flood insurance premiums, then real estate prices in those locations will likely fall. Even today there is evidence that coastal real estate at risk of flooding and hurricane damage is losing market value due to that risk (Cupal, 2015. Clayton, et al., 2021). This represents a potentially catastrophic risk to the real estate market, and the overall economy.

After identifying the immense amount of property at risk within the United States, it becomes clear that uncertainty is the only certainty in many areas of the US. Some locations, like New Orleans and Miami, face such extreme climate risks it appears likely they will face disinvestment and property value loss as a result of worsening climate change risks. Governments and property owners in these locations are already spending

hundreds of millions of dollars to secure their assets with gray (e.g. concrete and steel flood barriers) and green (e.g. floodable waterfront parks) resilient infrastructure projects, insurance, and on-site resilient building improvements (Beirbaum, et al. 2012).

Resilience solutions that reduce environmental risks make the timeline for climate change effects on real estate values hard to predict in specific locations. It is important to consider a scenario with two neighboring locations, one area with relatively higher environmental risk and higher real estate values, and another with relatively lower risk and lower real estate values. The area of higher environmental risk in 2023 could be more resilient to environmental change than the area of lower risk. This can occur when areas with higher real estate values are prioritized for state and federally funded resilience projects, as well as the fact that areas with lower real estate values generally have smaller tax bases to adapt. This furthers the case that building resilience at the community level has direct financial benefits to individuals and businesses in that area. While sustainability is about preserving the natural systems we rely on over the long term, protecting the health and safety of all humans, and softening the impact of climate change on Americans long-term, building resilience is about saving a city, community, or property from current and near-term locally experienced impacts of environmental change. Locations can be described as 'naturally vulnerable' or 'resilient to environmental change' in 2023, but that is not a fixed description since environmental hazard risk can be lowered with resilience solutions (which often include sustainability solutions as well), or increased with updated projections of environmental change.

Finance, Insurance, Real Estate, Environmental Change and the Next Financial Crisis

Finance, insurance, and real estate markets act as a crucial trio, with each relying on the other for security and stability, and each playing an important role in the health and prosperity of the overall economy. One of the best recommendations for homeowners, investors, and renters is to simply buy the appropriate insurance policy for your risk, so governments should further inform and incentivize this action. For many mortgagors it is required that they obtain appropriate insurance, and for those with a federally-backed mortgage, it is always required (FEMA, 2021. Englander, 2020. Pogue, 2021). A standard mortgage loan in the United States can last for a 30-year term, so this paper will use a thirty-year horizon for thinking about medium-term risk as opposed to current short-term risks. The further forward we project, the more uncertainty there is. In *Moving to Higher Ground*, John Englander points out that 2100 is simply too far in the future to plan around given our life spans and how we think about risk, and that "nothing much is built or financed without reasonable confidence about the security of the assets over their useful life" (Englander, 2020).

The National Flood Insurance Program provides Americans with affordable flood insurance, with the government stepping in as the insurer of last resort in markets that would be unprofitable for private enterprises to ensure flood risk broadly (Englander, 2020. FEMA, 2015. NLR, 2019). This public service provided by the federal government, paid for by taxpayers nationwide, is allowing people to live in places they might not otherwise inhabit if the prices, or availability of insurance, accurately reflects risks (FEMA, 2015. NLR, 2019). The government is actively improving the National

Flood Insurance Program, with its Risk Rating 2.0, finally updating its old flood maps based on a different environmental reality. These updates make rates more reflective of risk in the short term, making owners of high-risk property pay an amount closer to their risk profile in the pool of insured properties, to ensure the stability of the program for the long term. The problem is these changes are happening slowly, and with each year more private insurers of flooding and other events are put out of business as environmental change makes insurance an unprofitable business in high-risk areas. This allows people in high-risk areas to believe they are safe since they can still buy affordable insurance and money is pouring in to finance new developments. The scale of real estate, insurance and finance markets in the U.S. that support real estate is so crucial to the workings of our economy, as we saw in the 2008 financial crisis, that the under accounting for risk in real estate markets leads to systemic risks for the macro economy.

Introduction to the Impending Environmental Change-Induced Real Estate-Financial Crisis

The residential real estate market in the US, one sector of the overall U.S. real estate stock, represents over \$36 trillion in total value (Richardson, 2021). For comparison, the Federal government budget in 2021 was under \$7 trillion in total (US Department of Treasury, 2021). The residential real estate market grew by almost \$7 trillion in 2021 during the Covid-19 pandemic (Manhertz, 2022. Duca, 2021). Today, more than 15% of the residential properties in the US are already facing flood risk, with far more at risk over the next 30 years as climate change worsens (First Street Foundation, 2020). A recent study by the First Street Foundation found that over 50% of

residential properties face some risk of fire, while 7% faced risks that were characterized as *Extreme, Severe, or Major*.

The increasing environmental risks associated with climate change pose severe risks to the overall US real estate market within the next two decades. The magnitude and nature of risk to the real estate sector is a threat to the broader US financial system and overall economy that must be addressed to avoid a catastrophe that could be worse than the 2008 financial crisis (Richardson, 2021. Fox, 2013). In the lead-up to the 2008 financial crisis, the risk to property and mortgages was not properly accounted for, the underwriting standards were relaxed, and the rating agencies were stamping junk assets with high-quality ratings, while big banks were pushing for deregulations to allow for further profiteering in the world of big finance through mortgage-backed securities and collateralized debt obligations (Fox, 2013). Investors, lenders, and homebuyers thought prices would keep going up or at least not fall that fast, and they were very wrong. Real estate markets go through cycles, similar to financial markets, and in 2007 the market was at a peak, and 2008 was the valley-bottom (Crotty, 2009). In contrast, many individuals and institutions predicted a contraction in real estate values during the Covid-19 pandemic, however, prices continued to climb even more dramatically than before, due to low housing inventory, record-low interest rates, and Americans with money to spend (Duca and Murphy, 2021). The real estate market has been in a growth period lasting over 15 years since the last national contraction in prices (Duca and Murphy, 2021). Financial markets are pumping more money than ever into growing cities and towns across the country, many of which are also some of the highest-risk locations in the

country for environmental vulnerability, such as Miami and Houston (FEMA 2021. Fannie Mae, 2022). Florida and Texas are two of the fastest-growing states in population and real estate development, and two of the highest-risk states in the US (UCS, 2018). The changing environmental risks have not been factored into decisions made by consumers and investors.

Given the long building life cycle and limited time to adapt, the faster the resilience improvements can be implemented in the real estate industry, the more secure the overall market will be in the long run (Boland et al, 2020). With each year of inaction on resilience and worsening environmental signals, the projected long-term performance of the real estate industry will be 'written-down'. There will be tipping points, and the changes in value could come within a couple of years, despite the slowly increasing risks that have been creeping up for decades already (Brunetti et al, 2021). A single devastating storm or a season of them could cause insurance companies to simply cancel all their policies in an entire state or region (Keys and Mulder, 2020. Sigaud, 2018). This could cause a panic in real estate markets as mortgage holders, which require the collateral asset to be fully insured, scramble to get their assets protected or or sell out to avoid risking future default as a result of incredibly high insurance and financing costs that will come in the years to follow (Keys and Mulder, 2020. Sigaud, 2018).

Although the risk is dispersed across the country, the climate change-real estate crisis is a national issue, with the potential to crater the overall US financial system and economy (UCS, 2018. Worland, 2021. Meyer, 2019). It is also a local one, with certain

regions, states, counties, and cities facing extreme concentrations of environmental risks (UCS, 2018. Worland, 2021. Meyer, 2019).

The federal government acts as both the lender and insurer of last resort, resulting in a massive and unsustainable financial burden on US taxpayers. The federal government has several agencies and programs that support the US housing system, for example, the federal government purchases mortgages on homes and buildings from the banks that originated them to lower the cost of home-buying. Since the government is buying mortgages on the 'secondary market' from banks, the banks can offer better terms, but also they have less incentive to make sure the money they loan will be paid back, as long as they met the government standards for purchasing those loans on the secondary market, they were good to go (Fox, 2013). After the 2007/8 crisis, new regulations were put in place, including the Dodd-Frank Wall Street Reform and Consumer Protection Act increased the minimum required emergency bank cash reserves, more effective loss-sharing arrangements to avoid misalignments of incentives, and other reforms to protect consumers, by first making the banks that have come to underpin the system more resilient (US Congress - House Bill 4173. Fox, 2013). In the case of environmental change, the interests of the government and the banks are aligned in service of the lofty goals of stability and growth in unstable times, so there is hope for action on the financial side of the economy where systemic risks can topple the global economy if mishandled.

The federal government also funds major cleanup-rebuild projects after major disasters, often paying for homes to be rebuilt in the same places where a home was destroyed. This triple-threat of economic liabilities – insurance, finance, and disaster

relief for high-risk properties – represents a potentially catastrophic risk to the national real estate market, with repercussions for property values across the country. As explained above, these risks can be minimized with reforms to real estate finance, flood insurance, and disaster management programs funded by the government. The government is subsidizing risky behavior in an unsustainable manner. If action is not taken to address these issues, national financial markets and the overall economy could be pulled down by the under accounting for environmental risk in real estate valuation.

Environmental risks can be managed with resilience improvements and long-term planning, however, there are limits to the effectiveness of pushing back against nature (IPCC, 2022). Community-level resilience improvements, such as sea walls, and property-level resilience improvements, such as the placement of critical systems on the second floor instead of the basement, are examples of how owners can adapt their properties to changing environmental conditions (Pogue, 2021). Resilience can be built, however, for real estate owners who seek long-term financial security, owning real estate in a resilient location is more likely to provide economic security than building resilience in an environmentally-vulnerable location.

Table 2: Real Estate Building Value by State Categorized using FEMA Risk Rating

Rank	State	VLR + VRL %	VLR %	RLR %	MR %	RHR %	VHR %	Very Low Risk	Relatively Low Risk	Moderate Risk	Relatively High Risk	Very High Risk	State Total
1	Vermont	100%	80%	20%	0%	0%	0%	\$65,401,556,000	\$15,942,480,000	\$0	\$0	\$0	\$81,344,036,000
2	Wyoming	100%	71%	29%	0%	0%	0%	\$43,558,070,000	\$18,143,735,000	\$0	\$0	\$0	\$61,701,805,000
3	New Hampshire	100%	55%	45%	0%	0%	0%	\$93,034,852,000	\$75,652,266,000	\$0	\$0	\$0	\$168,687,118,000
4	North Dakota	100%	46%	54%	0%	0%	0%	\$36,100,311,000	\$42,712,766,000	\$0	\$0	\$0	\$78,813,077,000
5	Maine	100%	21%	79%	0%	0%	0%	\$33,498,205,000	\$129,175,125,000	\$0	\$0	\$0	\$162,673,330,000
6	Idaho	99%	30%	69%	1%	0%	0%	\$45,907,211,000	\$104,543,486,000	\$1,169,185,000	\$0	\$0	\$151,619,882,000
7	Virginia	97%	71%	26%	3%	0%	0%	\$717,929,628,000	\$259,434,386,000	\$33,178,823,000	\$0	\$0	\$1,010,542,837,000
8	Montana	88%	52%	35%	12%	0%	0%	\$56,538,445,000	\$38,144,981,000	\$13,362,901,000	\$0	\$0	\$108,046,327,000
9	West Virginia	87%	52%	35%	13%	0%	0%	\$101,169,829,000	\$68,810,296,000	\$25,877,255,000	\$0	\$0	\$195,857,380,000
10	Wisconsin	84%	46%	38%	0%	16%	0%	\$344,003,306,000	\$283,037,677,000	\$0	\$116,498,194,000	\$0	\$743,539,177,000
11	Delaware	76%	0%	76%	24%	0%	0%	\$0	\$92,377,909,000	\$29,088,935,000	\$0	\$0	\$121,466,844,000
12	Maryland	73%	35%	38%	17%	10%	0%	\$272,085,161,000	\$300,277,593,000	\$132,683,541,000	\$77,860,211,000	\$0	\$782,906,506,000
13	Massachusetts	72%	13%	59%	28%	0%	0%	\$113,696,782,000	\$522,427,293,000	\$250,100,919,000	\$0	\$0	\$886,224,994,000
14	Minnesota	65%	27%	38%	35%	0%	0%	\$195,149,388,000	\$267,764,782,000	\$250,056,946,000	\$0	\$0	\$712,971,116,000
15	Indiana	64%	25%	39%	36%	0%	0%	\$190,667,083,000	\$296,840,080,000	\$274,660,823,000	\$0	\$0	\$762,167,986,000
16	South Dakota	64%	36%	28%	36%	0%	0%	\$31,981,001,000	\$25,199,636,000	\$32,465,048,000	\$0	\$0	\$89,645,685,000
17	Kentucky	62%	25%	38%	16%	21%	0%	\$114,550,883,000	\$176,483,471,000	\$76,480,717,000	\$99,101,964,000	\$0	\$466,617,035,000
18	Kansas	62%	15%	47%	38%	0%	0%	\$50,668,539,000	\$156,409,982,000	\$127,982,072,000	\$0	\$0	\$335,060,593,000
19	Pennsylvania	61%	21%	40%	28%	0%	11%	\$305,837,792,000	\$589,986,547,000	\$408,932,042,000	\$0	\$165,970,513,000	\$1,470,726,894,000
20	Iowa	56%	14%	43%	44%	0%	0%	\$52,118,381,000	\$164,434,489,000	\$168,400,679,000	\$0	\$0	\$384,953,549,000
21	Utah	56%	26%	29%	39%	5%	0%	\$65,537,255,000	\$73,505,525,000	\$98,684,444,000	\$12,241,252,000	\$0	\$249,968,476,000
22	Mississippi	54%	6%	48%	24%	22%	0%	\$18,054,992,000	\$133,411,730,000	\$66,752,908,000	\$62,298,890,000	\$0	\$320,518,520,000
23	Connecticut	52%	12%	40%	48%	0%	0%	\$57,560,192,000	\$195,701,911,000	\$234,980,351,000	\$0	\$0	\$488,242,454,000
24	Alaska	51%	32%	19%	49%	0%	0%	\$29,234,354,000	\$16,863,134,000	\$44,567,972,000	\$0	\$0	\$90,665,460,000
25	Ohio	50%	28%	23%	29%	20%	0%	\$395,014,042,000	\$329,508,963,000	\$419,296,934,000	\$291,144,196,000	\$0	\$1,434,964,135,000
26	Tennessee	50%	11%	39%	22%	12%	16%	\$73,436,287,000	\$270,703,242,000	\$149,176,177,000	\$0	\$111,560,225,000	\$685,386,753,000
27	New York	49%	9%	41%	12%	22%	16%	\$199,291,926,000	\$950,463,822,000	\$285,816,786,000	\$518,035,009,000	\$381,434,548,000	\$2,335,042,091,000
28	Georgia	47%	20%	27%	53%	0%	0%	\$215,206,685,000	\$295,168,808,000	\$564,126,631,000	\$0	\$0	\$1,074,502,124,000
29	Michigan	47%	24%	24%	35%	18%	0%	\$297,191,508,000	\$297,071,464,000	\$434,600,175,000	\$222,563,232,000	\$0	\$1,251,426,379,000
30	Missouri	46%	9%	37%	16%	32%	7%	\$62,462,870,000	\$261,975,227,000	\$110,048,123,000	\$228,197,756,000	\$46,880,213,000	\$709,564,189,000
31	Nebraska	46%	11%	34%	26%	29%	0%	\$24,041,624,000	\$74,187,725,000	\$55,125,222,000	\$62,073,500,000	\$0	\$215,428,071,000
32	Rhode Island	45%	45%	0%	55%	0%	0%	\$60,132,960,000	\$0	\$73,663,560,000	\$0	\$0	\$133,796,520,000
33	Illinois	42%	8%	34%	18%	0%	40%	\$134,670,755,000	\$545,723,620,000	\$287,361,528,000	\$0	\$655,385,994,000	\$1,623,141,897,000
34	Alabama	39%	11%	28%	36%	26%	0%	\$55,860,178,000	\$138,407,897,000	\$179,436,802,000	\$128,901,600,000	\$0	\$502,606,477,000
35	North Carolina	38%	2%	36%	58%	5%	0%	\$21,003,094,000	\$372,760,627,000	\$602,215,084,000	\$49,422,205,000	\$0	\$1,045,401,010,000
36	Arkansas	37%	2%	35%	47%	17%	0%	\$5,290,126,000	\$100,926,078,000	\$136,304,040,000	\$48,464,245,000	\$0	\$290,984,489,000
37	Oklahoma	34%	4%	31%	26%	40%	0%	\$14,476,327,000	\$123,582,646,000	\$104,580,233,000	\$160,534,837,000	\$0	\$403,174,043,000
38	Colorado	34%	20%	14%	54%	13%	0%	\$113,070,024,000	\$80,731,098,000	\$309,150,922,000	\$73,548,361,000	\$0	\$576,500,405,000
39	New Jersey	32%	17%	14%	51%	11%	6%	\$196,808,534,000	\$164,910,245,000	\$574,605,926,000	\$129,274,532,000	\$72,109,429,000	\$1,137,708,666,000
40	South Carolina	26%	1%	24%	58%	17%	0%	\$6,553,386,000	\$119,433,741,000	\$281,696,690,000	\$81,267,166,000	\$0	\$488,950,983,000
41	Louisiana	23%	5%	18%	45%	22%	10%	\$23,240,454,000	\$83,421,341,000	\$206,111,722,000	\$99,889,796,000	\$45,552,878,000	\$458,216,191,000
42	New Mexico	21%	5%	16%	66%	13%	0%	\$9,169,523,000	\$29,064,918,000	\$121,762,100,000	\$23,924,464,000	\$0	\$183,921,005,000
43	Texas	16%	2%	14%	23%	32%	29%	\$50,623,422,000	\$362,498,298,000	\$597,409,737,000	\$840,880,837,000	\$745,788,399,000	\$2,597,200,693,000
44	Oregon	16%	1%	15%	42%	42%	0%	\$5,377,085,000	\$59,562,168,000	\$173,194,362,000	\$171,486,452,000	\$0	\$409,620,067,000
45	Washington	15%	2%	13%	37%	48%	0%	\$15,123,033,000	\$93,226,735,000	\$274,507,012,000	\$358,483,994,000	\$0	\$741,340,774,000
46	Hawaii	5%	0%	5%	13%	82%	0%	\$21,142,000	\$8,264,594,000	\$19,586,541,000	\$122,921,415,000	\$0	\$150,793,692,000
47	Florida	5%	1%	4%	20%	51%	25%	\$15,093,572,000	\$89,726,985,000	\$433,065,112,000	\$1,125,429,927,000	\$556,348,502,000	\$2,219,664,098,000
48	Nevada	4%	0%	3%	8%	89%	0%	\$1,358,258,000	\$8,739,395,000	\$22,481,809,000	\$254,669,426,000	\$0	\$287,248,888,000
49	California	1%	0%	1%	8%	47%	45%	\$3,007,305,000	\$44,905,715,000	\$292,189,203,000	\$1,793,154,349,000	\$1,715,594,936,000	\$3,848,851,508,000
50	Arizona	0%	0%	0%	3%	96%	0%	\$722,084,000	\$2,185,271,000	\$19,666,960,000	\$608,858,813,000	\$0	\$631,433,128,000

Data from the FEMA National Risk Index (Risk Rating and Building Value Data). (FEMA, 2021). Table created by Jonathan Grobstein in Excel.

The scale of environmental risk to real estate in the United States is enormous, and those risks are not spread evenly across the states. FEMA’s National Risk Index and the building value estimates provide a sense of the scale of the total value of real estate at risk from environmental change by state. This information also provides a high-level sense of the portion of real estate within a state that is vulnerable or resilient. This data, reported by state in this table but based on county-level data, shows that every county in Vermont and Wyoming has a FEMA Risk Rating of 'Very Low Risk' or 'Relatively Low Risk', while almost every county in California and Arizona has a FEMA rating of 'Very

High Risk' or 'Relatively High Risk'. This data also provides an estimate of the level of real estate value at risk on a national scale, with around \$4.5 trillion of real estate building value in the US located in counties rated as 'Very High Risk', or 13% of the total national stock of over \$35 trillion. These high-level metrics provide a general sense of the scale and locational diversity of risk in the United States. This analysis is limited by the real estate value estimates provided by FEMA at the county level, as well as the local differences in risk that are generalized in this analysis to provide a sense of the size of the issue at hand, which states are the most vulnerable, and which states are the most resilient to environmental change.

Shortcomings of Current Real Estate Sustainability Efforts and the Cobenefits of Adaptation and Mitigation

There's nothing sustainable about building a new energy efficient building that will be underwater or burnt to the ground within a matter of decades. While the focus of this paper is on adaptation, it is important to mention the significant efforts already underway to improve resource efficiency in real estate markets, and the shortcomings of those efforts. Resource-efficient buildings, sometimes called 'green buildings', show significant improvement in energy, water, and material usage, using up less resources than a comparable non-efficient asset (USGBC, 2021). Since the early 2000s, green building design and construction techniques have been implemented in cities around the country, incentivized by operational cost reduction, and often more favorable lending terms and zoning exceptions (LEED, USGBC, 2021). LEED (Leadership in Energy and Environmental Design), the most popular green building rating system in the US, has a

point system to rate the sustainability of a structure, similar to other comparable rating systems (USGBC, 2021). The rating system categories of LEED include: energy and atmosphere, water efficiency, sustainable sites, materials and resources, and indoor environmental quality (USGBC, 2021). What is missing from this green rating system and others is a category for the resilience of a structure to environmental change (Verdinez, 2021). A building should not be considered sustainable if it is at extreme risk of chronic flooding or fire. While limited in its resilience focus so far, the green building movement to date shows there is already a significant appetite for sustainability that is growing in the real estate sector (Verdinez, 2021).

Sustainability can be a confusing topic to many, especially asset holders, maybe because it seems to go against personal interest. 'Why should I not use energy and water when we have so much of it, and when others use even more than I do?' It usually comes down to the cost-benefit, 'if the government is paying for these solar PV panels and my bill will be lower' or 'the government is giving me \$10,000 to buy a new EV,' that is a strong incentive for sustainability. The long-term threat of climate change exposed in the most current scientific publications will likely not be enough for people to change, they will also need financial incentives or to experience actual damage before action is induced. The evidence is the lack of resource conservation in America today. We have more personal devices and appliances at our disposal than ever before, but fortunately, engineers have been able to vastly improve the efficiency of appliances, benefiting consumers on their energy bills. It will most likely take a series of catastrophic

environmental events and a resulting economic crisis to kick off the deep changes that our society needs to continue its prosperity in the era of environmental change.

To be clear, the mitigation of greenhouse gas emissions on a global scale is necessary for the continued prosperity of human civilization as we know it. However, without nationwide adaptation to environmental change, the American economy and quality of life will be degraded before our carbon emissions reductions lead to lower experienced impacts (UN-IPCC, 2022. Bendell, 2019). It is hard to imagine a scenario of a more peaceful, more democratic world when environmental change is inducing famine, economic crisis, and the potential for 500 million migrants looking for stable food, water, and security. The global climate crisis and thousands of local environmental catastrophes can also be harmful to life, economy, and property in the most resilient places in the United States, which could be devalued due to the macroeconomic impacts of environmental change around the world.

Given the uncertainties of looking 50 years or more into the future, it is understandable why investors and homeowners would question why paying a premium for carbon emissions mitigation is worth it for the incalculable long-term benefits of a single consumer taking a two- or five-minute shower, eating red meat, or driving a pickup. "Where is my benefit?" If the seller of a sustainability solution can't respond with "lower costs, and here's the payback period", then the potential buyer is more likely to say no. Americans need incentives to guide their interests toward a positive societal solution, instead of being forced, which can cause an equal and opposite backlash against the necessary changes. The slow adoption of electric vehicles and grid-scale solar and

wind farms would have been even slower if not for the strong subsidies provided by the government. Similarly, the government has historically provided trillions in tax breaks and subsidies to fossil fuel companies in the name of growth and energy security. The US military may use rechargeable batteries and solar arrays at scale because they are reliable, and are easier to transport to forward operating bases and battlelines than heavy oil or propane tanks. Sustainability is tied to resilience in many cases, such as a situation where renewable energy technology is tied into a microgrid with a battery, reducing dependence on fossil fuels and providing power in the case of a grid failure (Pogue, 2021).

Given the transition risks, such as fines for inefficiency or consumers paying a premium for efficacy, it is often financially beneficial to include resource efficiency improvements in adaptation planning. For example, an on-site or community solar array with storage tied into the main grid with an automatic switch to revert to storage power when the grid is down, can make a property or neighborhood more resilient than its neighbors during a crisis and reduce greenhouse gas emissions in steady times. A backup power improves resilience by allowing for operational continuity during a grid failure. Consider also that even if a property has solar panels as a source of energy in a resilient location, if the panels are poorly installed they could fail during an acute environmental crisis or put your home at more risk. Resilience and resource efficiency thinking must be tied together in all decision-making in the age of environmental change, and one without the other should be considered neither.

For a location and property to be considered truly resilient, there must be considerations of sustainability and resource efficiency to counter the indirect risks of

consumer demand changes and utility costs. Although it is difficult to predict future regulations, as climate change worsens, the cost of energy, water, materials, and polluting activities is expected to rise significantly. Properties and locations that act early to increase the ratio of renewable energy in their energy supply, build out charging infrastructure for electric cars, and incentivize green business activities, will likely have lower future operating costs and more discretionary funds available to manage crises or improve the quality of life of residents. On-site or community renewable power generation, and storage is an ideal way for communities and properties to reduce their dependence on a vulnerable fossil fuel-reliant grid system, in many locations. Planting native species that are naturally resilient to the main environmental hazards faced, can provide mitigation and adaptation benefits simultaneously. The list of co-benefits between mitigation and adaptation is endless.

SECTION II: RESILIENT REAL ESTATE

Resilient Real Estate: An Introduction

The under-accounted-for environmental risk in the valuation of US real estate represents an investment opportunity, due to spatially varying risk and the limited adoption of climate change information in medium- and long-term value projections and investment decision-making. Some investors are already considering environmental factors in their investment decisions, but most are not, and it is becoming clear that those

who move early may reap additional benefits beyond standard risk management competence. All investors should consider environmental risk in their projections of property profitability and value, and those investing in high-risk locations will need to consider environmental risks to ensure their financial security (Clayton, et al. 2021. Boland, et al., 2021. UN-IPCC, 2022. FEMA, 2021). This research will seek to provide evidence that properties in high-risk locations are overvalued, and properties in low-risk locations are undervalued. American land is a limited resource, and resilient American land is even more limited.

What is Resilience?

“The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.” (UN-IPCC, 2022).

“The ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.” (US Department of Defense, 2021)

In other words, resilience is the ability of a system to survive, preserve value, and continue normal operations during and after a crisis. In the era of climate change, individuals, groups, and assets must be able to withstand the impacts of environmental change to be considered resilient overall. To be comparatively resilient in the era of

environmental change is to be located in a naturally resilient location, or to build resilience to risk. The opposite of resilience is vulnerability, and those people and assets in locations with severe environmental risk can be considered *vulnerable*, in the sense of comparative environmental risk.

There is a distinction to be made between natural resilience and built resilience. Areas with low-environmental risk due to their location alone may be said to have natural resilience, where ‘built resilience’ is not needed for an entity or property in those areas to be considered environmentally-resilient. In vulnerable locations, the physical risks of climate change must be addressed and adapted to for a property, company, or community to be considered comparatively resilient to its neighbors. There is a crucial spatial component to the topic of environmental impacts on assets in that environmental change is spatially diverse and the value of similar assets is tied together within a market. If a property has built-resilience improvements – such as a property-level sea wall – it can still face devaluation due to its local market risk profile, meaning there are limits to the economic logic of built-resilience in the highest-risk locations (Clayton et al, 2021. Pogue, 2021).

Defining the Categories of Resilient Locations and Property

In this paper, locations that are projected to be the most resilient to environmental change in the United States will be considered *Nationally-Resilient Locations*, and land within those locations as *Nationally-Resilient Land or Real Estate*. Properties that are located in regions with significant risk can still be considered resilient, due to their place in a *Locally-Resilient Location* with significant environmental risks that are still

substantially lower risk than their neighbors, or through built-resilience solutions. Real estate or land that is substantially more resilient to environmental change than the local/regional market standard will be defined in this paper as *Locally-Resilient Real Estate*. To label all locations and properties in the United States using these new definitions, I will add the category of Neutral-Resilience, to be used in the local or national sense, to define locations and properties that face comparatively moderate risk.

The Levels of Environmental Risk and Resilience

To analyze environmental risk and potential resilience solutions for communities and properties, it is critical to consider the how individuals, properties, and the multiple levels of government experience the impacts of change in different ways, and have different tools for adapting. Environmental change poses risks to people, property, communities, cities, states, and nations. Each level of risk – ranging from personal-level risks to federal-level risks – will be impacted by environmental change in different ways. The concept of the levels of risk and resilience is helpful as a framework for evaluating environmental risk and formulating adaptation solutions. The interdependencies of resilience across the levels make the problem more complex since an individual or property will struggle to maintain resilience in a vulnerable city or nation. However, this complexity provides opportunities for synergies in addressing multiple levels of risk and building support for those solutions at multiple levels.

Personal-Level Resilience:

At the personal level, environmental change represents a risk to the health, security, and wealth of Americans (IPCC, 2022). The vulnerability of individuals

depends primarily on their location, health, and economic assets. Individuals in a current state of vulnerability – potentially due to living or holding property in a vulnerable place – can improve their resilience to environmental change by moving to a resilient location, constructing/retrofitting their homes/buildings with resilient building solutions, and buying proper insurance coverage for health, life, and property. A more indirect strategy individuals can take to increase personal resilience is to demand resilience measures be implemented in their area by the local, state, and federal governments. Perhaps the most critical personal-level resilience measure is to build a 'rainy-day fund' or emergency account, to be able to rebuild and relocate during and after an acute environmental crisis.

Property-Level Resilience

At the property level, environmental change poses risks to the value and operation of buildings, homes, infrastructure, and land (e.g. agriculture and timber land) across the country (UCS, 2018. First Street Foundation, 2021). As extreme wildfires and extreme floods consume thousands of properties each year, costing individuals, insurance companies, banks, and cities billions of dollars in damages, real estate decision-makers must consider how to reduce their financial risks from environmental disasters to be financially secure (Pogue, 2021. Clayton et al, 2021. Sheldon, 2019).

There are many options for making new buildings resilient to local environmental risks, as well as options for retrofitting existing buildings to be more resilient. For new buildings, some examples of resilience solutions include building above grade, locating utilities and mechanical equipment on the 2nd floor instead of the basement, flood management landscaping, sealing building envelopes, building with non-flammable

materials, and on-site flood barriers (Pogue, 2021. Coaffee and Lee, 2017). Many property-level adaptation solutions can be retrofitted into an existing building, but the costs are higher, and the effectiveness is reduced as compared to when resilience improvements are included during the initial design and construction of a new building. One of the most important steps that building owners can take, for both new construction and retrofitting, is to purchase accurate insurance coverage that will cover the costs of projected damages caused by local environmental hazards. The federal government – through FEMA, NOAA, and other agencies –, local governments, non-profit scientific organizations like the First Street Foundation, and other institutions provide a wide variety of information and recommendations for free online to help property owners prepare for environmental change.

During an acute environmental crisis, an individual property may not be directly damaged, but could still lose operational continuity due to infrastructure damage in the surrounding area (Clayton et al, 2021). An individual or property will struggle to maintain resilience in the era of environmental change if they are located in a vulnerable community (Pogue, 2021). The various levels of risk and resilience are intertwined, with the actions of the individual impacting the resilience of the property, the resilience of the single property impacting the resilience of the community, and down the ladder or pyramid of levels, moving in both directions. Each level impacts every other level in some way and these relationships add complexity to predicting the impacts of environmental change on individual properties or the market at a whole. For real estate

stakeholders, each scale must be considered in the determination of an individual property's level of risk and possible resilience improvement measures.

The property-level solutions for resilience to environmental change can range from short-term acute disaster resilience measures – such as plywood for wind, and sandbags or an inflatable flood barrier for water –, to longer-term measures – such as sealing the building envelope, securing the roof, and having a backup power supply (UN-IPCC, 2022. Climate Ready Boston, 2021. Pogue, 2021). Many of the most effective long-term engineering solutions are expensive, for example, raising the entire structure off the ground and physically moving it away from risk is an expensive proposition. Most home owners will not have money or option to make expensive adaptations and will be forced to deal with the risks with less-effective short-term fixes, or by finding a safer place to live when the risks to life become too high (UN-IPCC, 2022. FEMA, 2021). The cost-benefit analysis of resilience planning and implementation projects have been widely studied and reported, which have explained with data what we have known for centuries that an *ounce of Prevention is worth a pound of cure* and it is best to *hope for the best and plan for the worst* (Pogue, 2021. GBCI, 2020. Johnson, et al., 2019).

At the property level, there are many synergies between sustainability, resource efficiency, and resilience. An example of a property-level resilience solution that also reduces carbon intensity is the ability to produce renewable power on-site – through solar, wind, or geothermal systems – before, during, and after a crisis, especially for locations vulnerable to electricity interruptions (Pogue, 2021. Krueger, 2018). Synergistic resilience solutions offer opportunities for property owners to address the physical and

transition impacts of environmental change simultaneously, while also addressing resource efficiency, all in a cost-effective manner.

As the climate crisis worsens, more Americans will become aware of their impacts on the environment and will be more likely to seek out sustainable living options (Hino and Burke, 2021. Clayton, et al., 2021). The transition risks and physical risks to real estate can have direct impacts on the profitability of investment properties and the value of residential homes, as consumers demand more resilience and sustainability in their real estate decision-making. Higher insurance premiums, real estate taxes, and energy costs can significantly reduce the value of property (Clayton et al, 2021).

Community-Level Resilience (Neighborhood/Town/City)

Resilience at the local community/neighborhood/town/city-scale has crucial impacts on the resilience of individuals and properties. People rely on their communities, especially in a crisis, to provide critical resources, such as water, food, electricity, shelter, and transportation, that can become difficult to access when environmental conditions change rapidly. Property owners and businesses rely on their communities for the critical resources that keep their businesses operating during stable times, and even more so during times of crisis. It is possible, but challenging, for an individual or property to be made resilient while being located in a community/neighborhood/town/city that is highly vulnerable to environmental change. Site-level resilience solutions, such as raising homes off the ground or constructing with fire-resistant materials, can improve the resilience of one property over another, but if the community as a whole is vulnerable, the more

resilient of the properties will still face a significant risk of devaluation related to their community/market vulnerability.

Communities and local governments that invest in town/city-level resilience solutions are likely to see positive returns on those investments over time in the form of saved costs (GBCI, 2020. UN-IPCC, 2022. Eichholtz, 2013. Johnson, et al., 2019). In a community, town, or city, people often have more in common with one another than with a random person in the state or country, and individuals can have a greater influence on local-level actions. Communities can come together and demand resilience spending from their government to improve the health, safety, and prosperity of the community and the individuals within.

Communities and local governments are incentivized to improve property-level resilience because their budgets are most often funded by local real estate taxes, which are determined based on the value of the property being taxed. Taxes on real estate fund schools, community improvements, and emergency services, the quality of which impacts the value of homes. Local governments, and their constituents, have aligned incentives to build resilience, which drastically increases the likelihood of resilience action.

At the city/town level, many local governments can regulate real estate development through zoning and building codes. This allows them to incentivize and/or require real estate developers to design and build for resilience in all new construction and major renovation projects. In high flood-risk areas, new buildings must be constructed above grade, with building systems on the 2nd floor instead of the basement. In high fire-risk areas, new buildings and major renovations must be constructed with

fire-proof materials. For all areas, investors/developers who construct a new building pay a fee or tax into a local resilience fund for community-level resilience and sustainability improvement projects.

At this scale, it is also more manageable for local governments to consider all stakeholders and come to a solution that benefits the community while minimizing maladaptation. Maladaptation is when attempts to adapt or build resilience leads to more harm than good, and wastes dollars that could have been spent actually reducing vulnerability. Local governments are often on the front lines of the battle against environmental change due to their direct connections to individuals in the community, and have built up knowledge and experience dealing with local environmental crises.

The problem is that many local governments have very limited budgets and lack the funds or scale to implement necessary resilience projects for their community. In some areas, usually affluent ones, local governments have large budgets, due to higher real estate values, and thus higher tax revenues, so they can more effectively fund resilience efforts in the community. For poorly funded local governments, it is not often feasible to take effective resilience measures without funding from the state or federal government.

Community-/City-/County-Level Real Estate Resilience Solutions

The majority of Americans who live in cities or in areas surrounding cities can take action to improve the resilience of their communities through advocacy for new policies and projects at local level, such as updates to zoning and building codes and resilient infrastructure projects. Local governments can choose to use their powers over

construction, real estate transactions, and real estate taxes to implement new development/sale taxes to fund resilience and move individual incentives toward resilient decision-making (Coaffee and Lee, 2016).

Through zoning and building codes, local governments can require resilience measures for all future development and major renovations. Local governments can implement building requirements that force developers to use resilient design and construction methods and materials (Climate Ready Boston, 2021. Coaffee and Lee, 2016). Local governments can also increase the allowed zoning density of structures by raising the allowed floor area ratio (FAR = total floor area of a structure divided by the land area it is built on) to encourage development of more housing units or commercial buildings in areas that are resilient.

When discussing resilience improvement projects at the city scale, people often think of gray-resilient infrastructure – concrete, steel, and asphalt solutions, such as seawalls, levees, raised roads, hardened assets, etc. A number of more natural resilience solutions exist in the realm of green-resilient infrastructure – more natural solutions - such as floodable waterfront parks and ecosystem enhancements of native plants that are resilient to environmental change (Coaffee and Lee, 2016. Bierbaum, 2012).

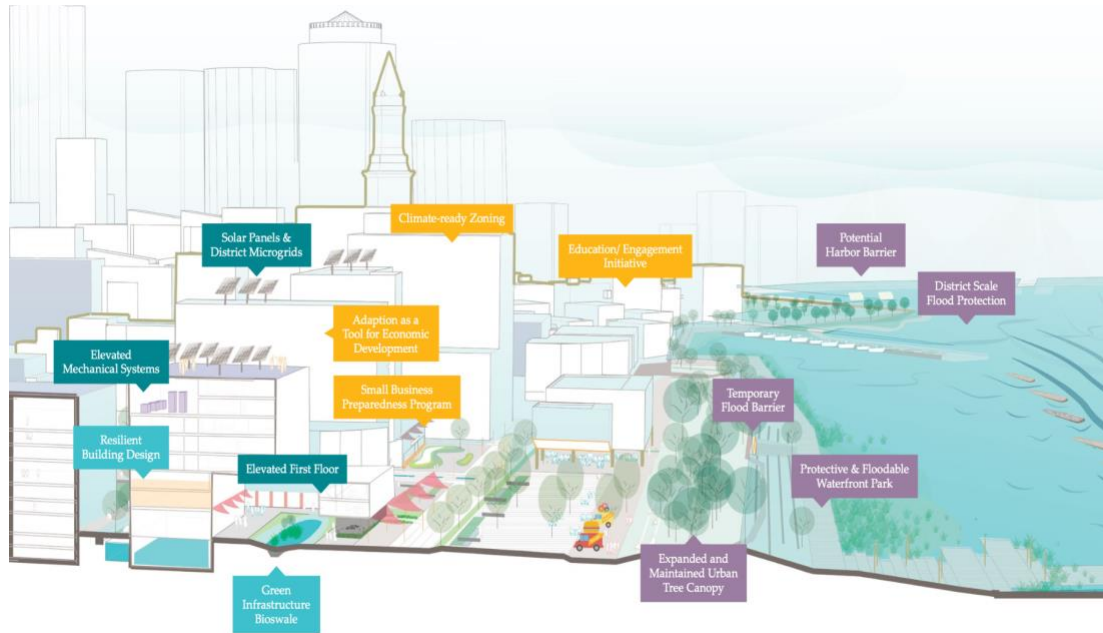
Policymakers should incentivize high-risk communities and property owners to move to lower-risk areas nearby over time (Englander, 2020). In the most vulnerable locations, the most effective, sustainable, and affordable solution is often a managed retreat (Carrey, 2020. Englander, 2020). This can be achieved in many different ways including through zoning and building code changes that require such an expensive level

of resilience on-site that new development is slowed in high-risk areas, by instituting new taxes on the highest-risk property, or through the direct purchase of extreme-risk property by the government through the market or eminent domain, to achieve the result of lowering the number of people and property at risk within the city or county lines (Coaffee and Lee, 2016). The policies that encourage the movement of people, assets, and growth to the most naturally resilient portions of a community can be implemented at different speeds depending on the level of risk, community support, and funding. It is becoming a question of “when”, not “if”, some American cities, including Miami and New Orleans, will need to begin implementing a managed retreat strategy to protect people and property at large.

Disasters, manmade or natural, can happen anywhere even in locations considered to be least vulnerable. All communities/cities/counties should have disaster management plans in place for alerting the public early about threats and guidance to survive them and protect property (Pogue, 2021. FEMA, 2021). Will emergency services, critical resource systems, and building systems continue to function in a crisis? These are critical questions to consider for any local government, business, or individual to consider in the era of environmental change. Individuals and entities can take action to improve their sites and financial security up to a point, but they will still rely on the politicians they vote for who can coordinate resilience efforts with other localities and the state and federal government to improve the community resilience that can impact the value of real property. Bringing in the state and federal government expands the pool of funds, knowledge, and political support for local resilience projects that directly impact the

financial health of the individual American in the age of environmental change.

Figure 5: Multi-Tiered Resilience Solutions Graphic (Climate Ready Boston, 2021)



This figure shows the potential for multiple levels of resilience improvements in Boston's downtown waterfront. The purple titles representing potential city/neighborhood-level resilience solutions, the orange titles representing zoning and educational resilience solutions, and the blue titles representing building-level solutions. The image is from the Climate Ready Boston plan released by the City of Boston's Planning and Development Agency in 2021.

State-Level Resilience

State governments have a duty and an incentive to build resilience within their borders to protect their people and economy. State governments have the budgets, expertise, and systems to promote and improve the scale and effectiveness of property-scale and community-scale resilience projects and campaigns. State government leaders can inform the public about the risks of environmental change and individual solutions,

implement state-level disaster plans, and encourage local resilience policy through carrot-and-stick incentives.

Not every town and city can afford to develop a customized resilience plan, so each state should have a publicly available general resilience planning guide available to all. States are especially important in organizing and funding expensive resilience projects that also generally require coordination between localities and agencies.

States also have more control over the utility grids that our communities and economy rely on, and thus have a duty and an opportunity to improve their overall resilience by hardening their electricity and gas grids to ensure people can get the power they need during stable times and during a crisis (Bakke, 2017). Major grid overhaul projects often go beyond a single state, extending across regions, which means individuals must not only rely on their local governments but also the state government and federal government.

Large resilient-gray-infrastructure projects like dams and sea walls, at the city/regional scale, can easily cost billions of dollars, often take decades to plan and complete (Bierbaum, 2012). Most cities and towns cannot raise billions of dollars beyond their current budgeted revenue, meaning those large projects that could provide benefits to millions can be too expensive to attempt for a locality, and even a single state government may struggle to fund the bill for the largest projects.

Federal-Level Resilience

The federal government has the money and institutional power to fund and incentivize resilience at all other levels, with the tools to impact the actions of individuals

and property owners as well as businesses and state governments to encourage further resilience measures. The federal level of government can provide the necessary financial backing for resilient infrastructure mega-projects, coordination of policy and action between states and agencies, providing information to the public through federally funded research, all to limit the risks to both economic security and national security (UN-IPCC, 2022). Certain projects will not be undertaken without the support of the Federal Government due to the cost and challenges of massive infrastructure projects such as large coastal resilience projects that can cost tens of billions of dollars and take decades to complete (Bierbaum, 2012).

The federal government has the resources and knowledge to adapt to the crises – it produces or funds a majority of the research to understand, mitigate, and adapt to environmental change – but it has failed to take significant action to address real estate resilience. The US Department of Defense considers climate change to be a ‘risk-multiplier’ and one of the greatest threats to America’s security in the 21st century (Motta, et. al., 2020. U.S. Department of Defense, 2021). It is past time for Americans – especially homeowners, politicians, scientists, and businesspeople – to treat climate change as a threat to American security.

The federal government can also play a significant role in property-scale resilience improvements due to national real estate market mechanisms that underpin our economic system, which can be adjusted to force resilience at the individual level. For example, a Fannie Mae mortgage contract already requires the borrower to have flood insurance on the subject property if they are in an area of risk according to a FEMA risk

rating system. As we have discussed in this paper, the FEMA maps do not accurately reflect the risks of properties today and ignore the forward-looking threats of environmental change. This immense problem has reasonable solutions to begin the process of lowering risk nationally. Many of those solutions require the weight of the US government to incentivize the banks, insurers, and asset managers to reduce the structural risks to the US financial system, and thus act in their own interest. Without coordinated efforts from the federal government, resilience will be a decision left up to states and localities; some will have the will and resources to build resilience on their own, while others will not.

Environmental Change, Migration, and Real Estate

This paper would not be complete without a basic introduction to the topic of ‘climate-migration’, which has become a popular topic in government, academia, and media, both in the context of animal habitat changes and humans moving to avoid environmental risk. The popularity of this topic is likely due to the scale of potential migrations and the consequences of those migrations on economics and politics. International climate migration is not the focus of this paper, however it is especially important to consider international migration when investing in real estate near national-borders or in gateway cities. Environmental change is projected to induce the migrations of hundreds of millions of people this century, with extensive impacts on economics and politics at multiple levels (UN-IPCC, 2022.). Whether we are discussing international or domestic migrations, the forces at play are often similar, and these forces are known as the push and pull factors of migrations. Perhaps the most common push factor is lack of

job opportunities, pushing people out, and the most common pull factor is the appeal of job opportunities, pulling people in. Other push and pull factors can include many factors influencing the quality of life in a location in terms of social, financial, political, and religious freedom and security. The most vulnerable locations, that are likely to see economic losses as a result of increasing risks, are likely to have their pull factors diminished while their push factors increase. For example, Americans moving South for good weather and lower taxes may be forced to reconsider the logic of that reasoning as the risks of extreme weather events increase and require more costs on the part of the individual in terms of property operation, financing, and ownership.

This paper will introduce the topic of domestic migrations that can be induced by environmental change, and lead to changes in the value of real estate in the United States. There are countless instances of environmental disasters causing migrations in this country. The Dust Bowl in the 1930s forced millions of Americans in the Southwest and Plains regions to leave their degraded lands that had turned to dust as a result of damaging agricultural practices and limited resources to adapt. More recently, Hurricane Katrina forced thousands of Americans to leave New Orleans in the aftermath of the 2005 hurricane that flooded thousands of properties. Americans have been forced off their land by nature before, but the modern environmental crisis is a more difficult situation to adapt to. The global scale and worsening trajectory of this crisis can not be overcome in the way that an acute crisis can be overcome once the dust has settled. The environmental changes we are beginning to experience in the United States will not lead to the sort of localized crises that have been a part of humanity for all of time, the types of crises that

can generally be recovered from once the destruction is over, and lead to opportunities for living and building smarter in the locations next iteration. The twenty-first century environmental crisis is a chronic, terminal illness for certain locations, even if they have a history of overcoming acute environmental disasters. Domestic migration as a result of environmental change is an important concept for real estate investors to consider, especially those who hold real estate long-term or investors with assets concentrated in a single local market.

Some of the states at the highest risk, including Texas and Florida, are some of the most popular destinations for domestic migrants moving between states in recent years (Kiersz, 2018). This is one of the reasons why the populations of Texas and Florida have been growing more quickly than the national average from the past two decades, leading to rapid growth in real estate values (Davis, 2017. US Census 2020). Many of the domestic migrants moving South are retirees looking for lower income taxes, warm weather, and beaches (Smith and House, 2006). As the coastlines get further developed, the number of people and the property at risk are growing (Davis, 2017). These places could see significant out-migration in the coming decades, of humans and capital, especially among their highest income residents who often live in the most expensive, and highest risk, beach homes, and have the most resources to move elsewhere. The most resilient locations can be expected to see increases in incoming migration, possibly reversing current migration trends in the opposite direction, forging new migration pathways (McLeman, 2015. Piguet, et al., 2011).

These projected changes in migration patterns as a result of environmental change should be considered by long-term-hold real estate investors, and by governments at the local, state, and federal level in order to build scaled resilience while managing the impacts of migration flows.

In terms of domestic migrations, people are most likely to travel short distances, so areas of low risk near areas of high risk are likely to receive environmentally-driven migrants. This could include high elevation areas near coastal areas with high flood risk. Also as was discussed earlier in this paper, areas that are projected to be the most resilient to climate damage in the future may receive more long-distance domestic migration of people seeking environmental security.

Climate Resilient Real Estate

Resilient assets are those with the robustness to maintain operations and asset value during and after an acute or long-term crisis. In one of the few peer-reviewed research papers to address climate-resilient real estate, Professor Jim Clayton provides an initial definition for 'resilient assets': “Resilient assets are those able to withstand the effects of not only acute disruptions in the market but also chronic longer-term threats.” (*Clayton et al, 2021*). Resilient assets are not only able to withstand direct environmental hazards, but also the indirect changes that result from environmental change (*Clayton et al, 2021. Boland, 2022. Hino and Burke, 2021*). In the event of an acute environmental disaster that leads to local infrastructure damage, loss in the local tax base, increased tax rates to pay for damage and make up for lost tax base, strains on services, and higher

insurance premiums are all indirect effects of environmental change on real estate with implication on long term value (Clayton et al, 2021. Hino and Buke, 2021).

To determine if a property is resilient requires consideration of risk and resilience at other levels, the personal level, city level, state level, and federal level. A property can be resilient on-site, but if the neighborhood or town surrounding the home is underwater or burnt to the ground, then the subject property is not very resilient (quality of life reduction and asset devaluation is expected). This means that the most resilient locations in general are those in areas that naturally have low vulnerability and qualities of economic robustness.

My definition of Environmentally Resilient Real Estate:

Environmentally Resilient Real Estate – property that is either nationally-resilient or locally-resilient – is projected to retain value or grow in value, despite the overwhelmingly negative projected impacts of climate change on real estate markets, while also operating efficiently in steady times, and continuing to function during and after an acute environmental crisis.

In a recent book focused on informing individual and community adaptation and resilience to environmental change, author David Pogue lists four rules for migrating towards resilient locations; 1) Get away from the oceans 2) Move north 3) Find Fresh Water 4) Seek infrastructure (Pogue, 2021). These four rules of resilience can serve as the base characteristics for identifying comparably resilient places and properties.

National Resilience vs. Local Resilience

A distinction must be made in the discussion of resilient real estate, one that I have not found made before. When discussing vulnerability and resilience, are we comparing the property's risk and value to the national real estate market or the local real estate market? We must differentiate between the locations and properties that are resilient compared to their neighbors, or *local resilience*, and those that are the most resilient in the United States, or *national resilience*.

Defining Nationally-Resilient Property

Nationally-resilient property is located in the most resilient locations to climate change in the United States, with the current environmental conditions, natural resources, and economic and social infrastructure to be able to maintain economic stability in an era of environmental instability. The most resilient properties in the United States can be termed, '*nationally-resilient properties*'. Defining this sector of real estate allows us to have a baseline for assessing the vulnerability of other locations, and allows for a value to be placed on the rare characteristic of minimal projected environmental vulnerability. The value of properties in the most resilient locations should be expected to rise significantly in the 21st century, as the supply of resilient land falls with further erosion and damage to vulnerable properties, and the demand for resilient land grows from Americans seeking security.

The most resilient properties in the US are clustered in the most resilient regions and locations that the US has to offer, or *nationally-resilient locations*. The nationally-resilient locations are generally located in the northern states, inland, with freshwater and limited risk of flooding, wildfire, and extreme heat. The most resilient regions are the Midwest, the Northwest, and the Northeast, and the most resilient locations within those regions are inland, with limited flooding and wildfire risk, quality soil or timber, a strong economic base, and sustainable freshwater resources.

For nationally-resilient property, we can be reasonably confident that the resilient locations, and real estate within, will continue to be the most resilient options to avoid the negative impacts of environmental change in the US for at least 50 years, beyond which it is difficult to predict anything with significant accuracy, especially systems as complex as the global environment and economy. This means that the category of nationally-resilient property can be thought of as a long-term definition, with an outlook beyond 15 years, while locally-resilient property should be considered as a short or medium-term asset (becoming a liability over time, but more slowly than its neighbors), with an outlook of 5-15 years. For locally-resilient properties, it is unclear how long a resilient property can retain its value in a market facing extreme climate change impacts that put downward pressure on the value of real estate in the city overall.

It should be expected that *nationally-resilient locations* and *locally-resilient locations* will attract future migration along different timelines and for different groups of Americans. People in vulnerable areas will be pushed to find resilient places to live if changing environmental conditions lead to lower quality of life and economic decline.

The comparatively strong resilience of another location should be expected to pull people in and keep people there. The pull factors of family, work, and safety, are likely to compel individuals to choose resilient locations to migrate to if they are pushed out of their homes or communities by environmental change.

However, some notable current migration trends are moving in the reverse direction from the patterns that are anticipated to evolve in response to environmental change. Americans are moving to locations in the Southeast and Southwest in record numbers (IRS 2021, Census 2020). The current southward migration flows of the US population add to the vulnerability of those locations by driving up the population and real estate values to unsustainable levels. This provides further evidence that projections of environmental change are not being considered by the majority of Americans in their migration decisions. The current trend of domestic migrants seeking out vulnerable locations is one factor leading to the under accounting for environmental risk in real estate valuation in the United States in 2023.

Defining Locally-Resilient Property

In vulnerable locations the heterogeneous environmental risk between neighboring areas and properties can lead to disparate outcomes in close proximity (First Street Foundation, 2021. FEMA, 2021). This leads to the concept of locally-resilient property, which is in itself a value proposition for certain real estate in areas and on lots that are more resilient than nearby locations. In areas where immense real estate value is concentrated on the highest risk parcels, such as in Miami – where land is over-valued

due to its environmental risk profile –, there is a potential opportunity in the nearest locations that are resilient and also undervalued due to the under accounting of environmental risk in property markets in 2023. In a coastal city at a low elevation, the properties at a higher elevation within the city or in the closest suburbs are likely to comparatively hold value despite changing environmental risks and potentially grow in value, as the more vulnerable properties are devalued when their projected long term risks are realized in current values. Properties in environmentally-vulnerable markets that are significantly more resilient to the changing conditions in that market than the average property are likely to preserve value for longer than in high-risk locations. It is a potential outcome that in some high-risk markets, *locally-resilient properties* will grow in value, but it can be logically expected that the more resilient properties will preserve their value, economic use, and profitability for longer than the comparatively vulnerable properties in the same market. Despite this opportunity, real estate stakeholders should be wary of *locally-resilient property* investment as a truly 'resilient' strategy, since it carries the risk of holding long-term assets in high-risk markets. The value of locally-resilient property is still dependent on the economic success and demographics of the surrounding area. It is unclear if a *locally-resilient property* can be considered to be truly 'resilient' to environmental changes that will have impacts far beyond the physical effects of nature on individual real estate assets, we do not know if a property at a higher elevation in a city at high risk of sea level rise and increasing precipitation event severity will hold its value if the median home value and investment property incomes fall.

Since most people and businesses are tied somehow to their locations through employment, property, or personal relationships, the theory of locally-resilient property offers a refuge for those individuals, businesses, and people who will not move out of their cities or towns or off their lands as a result of the risks of the current under accounting for environmental change in local real estate markets. Locally-resilient properties, through the characteristics of the land itself or the method of construction, are significantly more resilient to environmental change than the average property in the same market. How long that feature of resilience will last for a locally-resilient property in vulnerable locations is not clear.

10 Examples of Resilient Cities and States in the United States

In the United States in 2023, there are several cities and states that stand out as the most environmentally resilient locations for real estate ownership and investment. The following list provides a small sample of the most resilient cities in the United States, informed by the general characteristics described and sourced in this paper (see table reference and works cited). While the discussion here is limited to cities, this is not to suggest these cities are more resilient than the suburbs, exurbs, and rural areas that surround the central market or city and provide it with people, resources, and goods, and rely on the value of the central location. These cities generally fall north of the 45th parallel, and the rankings incorporate social factors and real estate metrics in the sources referenced in this document, especially the FEMA National Risk Index, and the Rhodium Group's economic damage projections. Resilient locations in the United States are concentrated in the Midwest, inland Northeast and Northwest, and Upper Plains regions.

As temperatures warm globally and locally, northern regions with prohibitively cold temperatures in the present climate are likely to see some positive economic benefits of warming temperatures – due to more moderate living conditions, longer growing seasons, and longer outdoor labor seasons – up to a point.

Table 3: 10 Resilient States and 10 Resilient Cities Sample

Resilient State Example	Resilient City Example	Region	National Risk Index Rating (FEMA, 2021)	Economic Risk Rating 1-10, <i>most vulnerable</i> (Shaw and Lustgarten, 2021)	State Environmental Assets
Vermont	Burlington	Northeast	Very Low	4	Lake Champlain, Green Mountains, Proximity to Montreal, Canada
New York (Upstate)	Buffalo	Northeast	Moderate	4	Lake Ontario and Lake Erie, Catskills and Adirondack Mountains, Proximity to Toronto, Canada.
Pennsylvania	Pittsburgh	Northeast	Moderate	4	Lake Erie, Allegheny National Forest
Wisconsin	Madison	Midwest	Relatively Low	4	Lakes Michigan and Superior
Minnesota	Duluth	Midwest	Relatively Low	4	Lake Superior, Superior National Forest
Michigan	Ann Arbor	Midwest	Relatively	4	Lakes Michigan,

			Low		Huron, and Erie, Upper Peninsula, Proximity to Toronto, Canada
Washington	Spokane	Northwest	Relatively Low	4	Link to Seattle and Vancouver, Canada.
Idaho	Boise	Northwest	Relatively Low	5	Boise National Forest, Snake River
Montana	Billings	Northwest	Very Low	4	Yellowstone National Park
Colorado	Boulder	Southwest	Relatively Low	4	Rocky Mountain National Park

Table based on data and insights from the following sources: Shaw and Lustgarten, 2021. Pogue, 2021. FEMA, 2021. NCA, 2017.

The most resilient counties in the United States, as ranked by Shaw and Lustgarten in their report created for the New York Times and ProPublica in 2021, are located primarily in the Northern states in the Northeast and Midwest, with the notable exception of Colorado. In the table below from that report, the factors in the assessment of projected economic damage as a result of environmental changes include; heat, wet bulb, farm crop yields, sea level rise, very large fires. The combined risk score is on a scale of 1 to 10, with only six counties receiving a score of 1, located in Vermont, Maine, Michigan, and Colorado, representing the counties with the lowest negative impacts projected from environmental change. The report goes further to project economic gains in these counties as a result of environmental change mainly from higher crop yields as a

result of a longer growing season accompanying higher temperatures, that can also make life easier in cold locations (Shaw and Lustgarten, 2021).

Table 4: The 20 Most Resilient Counties in the United States - Projected Economic Damage from Climate Change (Shaw and Lustgarten, 2021)

County †	Heat †	Wet Bulb †	Farm Crop Yields †	Sea Level Rise †	Very Large Fires †	Economic Damages †
Park County, CO	1	1	1	1	5	1
Keweenaw County, MI	3	5	1	1	1	1
Grand Isle County, VT	3	4	1	1	1	1
Piscataquis County, ME	3	2	1	1	1	1
Essex County, VT	3	2	1	1	1	1
Orange County, VT	3	2	1	1	1	1
Cook County, MN	3	1	1	1	6	2
Washington County, ME	3	4	1	4	1	2
Lincoln County, ME	3	2	1	4	1	2
Hinsdale County, CO	3	1	1	1	3	2
Oxford County, ME	3	4	1	1	1	2
Caledonia County, VT	3	4	1	1	1	2
Grand County, CO	1	1	1	1	3	2
Aroostook County, ME	3	2	1	1	1	2
Franklin County, ME	3	2	1	1	1	2
Hamilton County, NY	3	2	1	1	1	2
Orleans County, VT	3	2	1	1	1	2
Lamoille County, VT	1	1	1	1	1	2
Mora County, NM	3	1	3	1	5	3
Houghton County, MI	3	2	3	1	3	3

Rhodium Group research reported on and organized by ProPublica. Shaw and Lustgarten, 2020.

From the same report, the table below identifies the counties with the most projected economic damage as a result of environmental change. Counties with a composite environmental risk score of a 9 or a 10 are projected to experience extreme

negative impacts on economy and society as a result of the environmental change factors included in the analysis by Shaw and Lustgarten. This analysis is missing several important factors, including freshwater availability and inland riverine flooding.

Table 5: The 20 Most Vulnerable Counties in the United States - Projected Economic Damage from Climate Change (Shaw and Lustgarten, 2021)

County †	Heat †	Wet Bulb †	Farm Crop Yields †	Sea Level Rise †	Very Large Fires †	Economic Damages †
Pamlico County, NC	4	7	8	6	2	10
Dixie County, FL	7	6	7	4	1	10
Levy County, FL	6	4	8	4	1	10
Franklin County, FL	4	6	1	4	2	10
Gulf County, FL	4	4	1	3	1	10
Beaufort County, SC	6	9	8	7	3	9
Wakulla County, FL	7	9	8	4	1	9
Assumption Parish, LA	6	9	7	7	2	9
Hyde County, NC	4	7	7	10	2	9
Volusia County, FL	4	6	8	4	3	9
Glades County, FL	9	1	8	3	3	9
Putnam County, FL	4	2	8	4	3	9
Vermilion Parish, LA	6	9	3	6	1	9
Clay County, FL	6	5	3	4	3	9
Carteret County, NC	4	7	3	6	1	9
McIntosh County, GA	6	9	1	4	2	9
Washington County, FL	4	2	6	3	1	9
Hancock County, MS	4	6	1	6	2	9
Citrus County, FL	9	4	1	4	1	9
Calhoun County, FL	4	2	5	1	1	9

Rhodium Group research reported on and organized by ProPublica. Shaw and Lustgarten, 2020.

SECTION III – OPPORTUNITY FOR RESILIENT REAL ESTATE INVESTMENT IN THE ERA OF ENVIRONMENTAL CHANGE

How should Real Estate Stakeholders Adapt to the Changing Environment?

Building resilience is critical to preserve the economic value of property in places with extreme risk (FEMA, 2021. IPCC, 2022). In extreme/high-risk places, the ‘sustainability’ of a building is dependent on its resilience, not on its carbon emissions. It is misleading to call a building ‘sustainable’ that is projected to flood chronically in twenty years. It is critical that policymakers, homeowners, and investors, those with the greatest ability to impact the resilience of their community, adapt their thinking to consider environmental vulnerability in all their real estate decisions. If homeowners, investors, and policymakers are made fully aware of the risk they face, they will have the personal incentive to invest in their own resilience and to support government measures that improve resilience at the community/state/federal scale. Homeowners and investors logically prefer not to hold risky assets that keep them up at night, and policymakers don't want climate change to harm their communities.

Policymakers

Without the consideration of environmental risks, many Americans will continue to make decisions that put themselves and their families at risk over the long term. Americans have not been properly informed on the extremity of the impacts of climate change and do not understand the risk to their financial security, with the evidence being the current under accounting for long term environmental risk in real estate prices. Local

governments may not be fond of advertising the perilous environmental changes that are projected, but they are in the best position to both inform their community and take resilient action. Informing the public of their risks should be the number one solution that every community in the US has the resources to do. The information relating to the impacts of climate change and the vulnerability of specific communities is widespread. The information is already available from leading scientific institutions for free in most cases, and community governments can synthesize that information and convey it to their constituents in a trustworthy and actionable way. Larger local governments with the resources to do area-specific studies of risk and resilience (such as the Climate Ready Boston report) allow for a level of detail that is more valuable to the community than boilerplate solutions. At a minimum, local governments should inform their constituents of the true nature of the risk they face so they have a chance to do something about it themselves, even if there is no further action from the local government beyond citizen education.

For the most vulnerable locations in the United States the best option for long-term community resilience may be to manage retreat. For the state and federal government, this could mean avoiding investing the taxpayer dollars of Americans in the highest-risk locations. By providing funds for resilience projects in the highest risk locations, the government is helping to protect the assets of individuals and businesses, but it also can lead to a dangerous moral hazard. If the federal government is willing to invest billions in the protection of extreme-risk locations with built resilience and is willing to bail out Americans for their uninsured disaster losses, it allows people in those

locations to continue a business-as-usual approach. The extreme-risk locations are also likely to need continuing funds to stay resilient and keep the improvements at a level that meets the environmental threats of tomorrow. State governments and the federal government should invest in resilience only in the places with a chance of staying resilient into the long-term future. There will be the need for a triage approach at some point in time when the risks further overwhelm the systems we rely on, and governments and policymakers will need to make hard choices about where to invest their dollars to ensure the maximum security of all their constituents.

Policymakers should consider whether a managed retreat strategy is the best option in resilient investment decisions. If it costs less for the government to buy out the property owners in an extreme risk area for near market value through eminent domain than it does to effectively build resilience, then the option of a managed retreat should be prioritized. If the cost is lower to flee from environmental risk than to fight it with built resilience, then retreat is the preferred option. The cost of protecting the highest-risk areas will only increase with time as the impacts of climate change become more severe.

Maladaptation, or flawed adaptation, is a serious risk in this era, a risk that policymakers and individuals in vulnerable locations must consider when making asset allocation decisions for resilience (Schipper, 2022. Bakke, 2017). Large gray infrastructure resilience projects are meant to reduce vulnerability but can, in many cases, make locations more vulnerable, especially as experienced impacts exceed the original design and engineering parameters (Schipper, 2022. Bakke, 2017). During the consideration of a physical-resilience improvement project at any scale, a cost-benefit

analysis must consider the long-term cost of keeping a sea wall, floodable park, or resilient building effectively in place versus the cost of slowly managing a retreat away from risk. All resilience projects must consider maladaptation risk, which can provide a useful baseline for assessing the cost/benefit analysis of potential resilience measures. This balance can be managed by governments through incentivization, using zoning and building codes, taxes, insurance, and other mechanisms to change cost incentives, or through force, using eminent domain.

Low-income communities in vulnerable locations are less likely to have the ability to build resilience and are also less likely to have insurance coverage or receive government funds in the wake of a disaster (Gibson, 2019). In this research, I focus on the impacts on real estate in terms of value or market price and the implications for homeowners and investors. Tenants in affordable housing, as well as those who are homeless, face the greatest risk of injury from environmental changes, such as flooding and extreme heat, and have the least resources to get back on their feet after a crisis (Gibson, 2019). Low-income individuals who rely on subsidized housing are especially vulnerable to climate change since it can be very difficult to find affordable housing accommodations in most places (Desmond, 2016). If your low-income housing unit is flooded, it is difficult to find new accommodation quickly nearby with many others in the same position, overloading the limited systems that support affordable housing (Desmond, 2016. Gibson, 2019). The homeless are in an even worse position, with their bodies and personal property exposed to the increasingly harsh elements (Gibson, 2019). These groups are also less likely to have insurance on their personal property and are

more likely to keep their cash and valuables on hand, so each storm puts their financial security at risk, and their housing is less likely to be resilient to environmental changes (Gibson, 2019. Desmond, 2016). When disaster strikes, these groups will be hit harder and have fewer resources to recover from the damage (IPCC Adaptation, 2022. Desmond, 2016).

Individuals, Investors, and Businesses

The first step for any person or company to build resilience is to determine the environmental risk to the property and community utilizing basic online research tools, such as the FEMA National Risk Index Map, or the NOAA Resilience Toolkit (FEMA, 2020. NOAA, 2021). If the risks to a home are extreme then the cost of staying in that home is likely to go up in the form of higher taxes, insurance, and maintenance costs with implications for the value of the property (Clayton, 2020. Boland et al, 2022. Englander, 2019). Individuals and businesses in these locations should consider moving to a less vulnerable location, implementing a managed retreat strategy as opposed to a forced retreat later on, if that is a possibility. Individuals and businesses in moderate-risk locations should take the basic steps of assessing their property-level risk, buying the proper insurance coverage, and improving the resilience of their assets and operations. Individuals and businesses living in low-risk locations can still take steps to increase the comparative resilience of their real estate by prioritizing efficiency and critical system redundancy for an added layer of long-term security.

One of the most important things people in any location can do to protect themselves and their investments is to buy insurance covering the full value of their

property, for all known risks (Pogue, 2021. UCS, 2017). For those owners or buyers of real estate who are denied insurance or are quoted to pay extremely high insurance premiums, the best option is to not buy that property or move elsewhere fast before costs rise higher. This also implies that the costs of the overall operation of the property will continue to rise and the overall location is at risk of value depreciation as a result of extreme environmental risk.

For communities investing in resilient infrastructure, updating building codes, and incentivizing sustainability, it is also crucial to incentivize managed retreats for the highest-risk locations. Some areas are simply too expensive to protect, given the extreme risks, and reduce a community's ability to build resilience overall (UCS, 2018). One way to do this is by charging a stormwater tax to raise the cost of living for risky property owners who will likely require a bailout in the future (Carrey, 2020). This also can help to fund infrastructure improvements and emergency services (Carrey, 2020). Managed retreat is being implemented in programs at local, state, and federal levels, with governments and federal agencies buying the most vulnerable properties to destroy them, in order to lower community and national risk burdens (Sider, 2019). It is important to recognize locations that will not be efficient to protect from overwhelming environmental risks long term and to have people move out of those places before it gets destroyed and wipes out people's and communities' financial security. Hard choices, like a retreat, will be necessary to adapt to the 21st century (IPCC, 2022. NCA, 2017. UCS, 2018).

Renters

Renters who do not own the property they inhabit and are contractually tied to that property for one year or less in most cases, avoid the worst financial impacts of environmental change on real estate. Renters are also legally protected by the law that a rental contract is voided if the property is destroyed or unlivable. The social and physical risks to life, as well as risks to personal property in vulnerable locations, can impact renters and homeowners in similar ways, but the potential financial losses of physical and transition risks from environmental change are more limited for renters. For those who continue to live in vulnerable locations, it is simply more financially secure to not own your home. Renters' insurance can cover the painful loss of personal items, and the financial security benefit of not owning property in vulnerable places outweighs the classic economic benefits of real estate ownership – tax benefits, capital gains, and a wealth transfer device to the next generation – (Mahoney, 2022. Pagourtzi, 2003). For those who need to live in vulnerable places for work or family, renting is simply a better option than buying. It is also important for renters to consider that since they cannot significantly improve the resilience of their apartment, they can choose to live in an apartment that has natural resilience or built resilience to reduce their own risk to manageable levels.

Homeowners

The recommendations for homeowners to make themselves and their families resilient to environmental change are simple: 1) live in a resilient place 2) buy proper insurance coverage 3) make resilience improvements at the property scale. There are extensive resources available for free online with solutions for homeowners to improve the resilience of their property using a mix of insurance and physical improvements to mitigate risk. All property owners should do a basic environmental risk assessment of their assets by doing basic online research on the environmental risks that the community is exposed to (online free resources are available through your local government, FEMA, NOAA, DoA, First Street Foundation's Risk Factor tool, and other publicly available info).

Individuals living in vulnerable locations should do further research to determine the risk to their property to make sure they have proper insurance coverage, and to identify any physical vulnerabilities. This may mean calling in a building professional or an insurance agent to determine the level of risk for a property and the proper coverage or solutions needed to improve financial security.

Check if the town/city that a subject property is located in has a resilience plan or recommendations for homeowners in the area to improve resilience and lower insurance costs. If no plans or information are available on the topic of environmental resilience at the local level, individuals can ask their local government why that is the case and learn from their neighbors on how to build resilience. More resilient homes in an area leads to a more resilient community overall, so individuals are incentivized to both learn from and

inform their neighbors to achieve collective resilience. Individual homeowners can also seek to build political support for and vote for environmental resilience policies and candidates who support those policies at the local, state, and federal levels.

The best resilience solution for individual homeowners and renters is to live in a location with low environmental risk. For homeowners living in a low-risk location, it is always a good idea to assess the local level of risk and to purchase the proper insurance coverage. Investments in resource efficiency improvements can have co-benefits to property resilience, such as on-site power generation and storage. Individuals in low-risk locations can prioritize emissions mitigation to maximize environmental resilience (due to transition risks and local comparative resilience), while individuals in high-risk locations should prioritize adaptations to counter the physical risks of environmental change.

Investor and Businesses - Reduce Exposure to Risk and Target Resilient Locations

For investors, the goal is always profits, or in less blatant terms, to achieve the highest risk-adjusted return possible. In modern times, achieving long-term profitability requires considering the physical and market risks associated with climate change (Clayton et al., 2021). This means more environmental research and due diligence should be completed before any major real estate transaction (Sheldon, 2017).

Investors should assess the environmental risk to their portfolio and reduce portfolio exposure to high-risk locations. Investors should consider holding on to a comparatively resilient property in a vulnerable location (locally resilient) until

environmentally-driven price shifts begin to significantly impact higher-risk properties within the same market.

There is a significant opportunity for investors to act on information that a limited segment of the market has incorporated into their real estate decision-making. The impacts of environmental change on real estate described in this paper and backed by widespread public research will have significant market impacts in the short-term, with more catastrophic outcomes over long-term. Those who adapt to projected environmental change before they directly experience loss as a result of environmental change, can expect better outcomes than those who wait and respond only when the damage has already been done.

Investors seeking to hedge their real estate portfolios' environmental risk can target nationally-resilient properties with long-term investments. Over time a portfolio's asset concentration in vulnerable locations should be reduced while increasing the concentration of portfolio assets in resilient locations.

The Era of Resilient Real Estate Investment

Real estate values are only beginning to reflect changing environmental risks, but the era of resilient real estate investment has begun, in that billions of dollars are going into resilient real estate investment strategies (Lee, 2021. Pogue, 2021. Bendix, 2018). Since these strategies are likely already being implemented in the market, although for which there is limited public information or evidence, this paper will lay out some of the strategies that investors of all types will come to include in all of their real estate

decisions in the coming decades. The available strategies to hedge risk, or capitalize on environmental change, are many, and some are quite obvious, such as buying land at a high elevation in a market with significant coastal sea level rise risk. Perhaps the most obvious investment strategy to profit from environmental change, and possibly the most cynical, is to buy up property with water rights in areas with limited freshwater resources. The prime locations for this type of strategy is the Colorado river region which is struggling under extensive drought conditions, limited freshwater resources, and growing populations, leading investment companies such as Water Asset Management, LLC to buy up \$20 million in land with comparatively strong water rights in recent years (Tracy, 2023). On Water Asset Management's website, they give an intriguing but limited pitch, not going into the full detail of how they will take advantage of communities and individuals with limited freshwater resources, but making clear their goals to maximize profits in this domain. *“WAM’s core belief is that scarce clean water is the resource defining this century, much like plentiful oil defined the last. WAM’s investment process is focused on fundamental analysis based on deep, proprietary water industry expertise and access to a wide range of industry operators, regulators, and policy experts. Climate change is intensifying drought, flood, and fire. These factors provide an unprecedented period of transformation and investment opportunity for the water industry.”* - Water Asset Management Website. Freshwater is a limited resource that is required for human life, agriculture, and energy production; one of the easiest ways to tap into that resource is by purchasing freshwater-rich land in freshwater-poor areas. There is a limited supply of resilient land, and the demand for it will grow as vulnerable land is further eroded by

environmental change along with the economies on top of it. The era of resilient real estate investment has begun, and it will not be pretty.

Resilient Real Estate Investment Strategy

The current market value of US real property in many locations does not accurately match its risk profile. There is an opportunity in that under accounting for risk. Current resilience/adaptation research that focuses on vulnerability often does not take the step to include consideration of investment opportunity. When we bridge the gap between scientific research and investment strategy, the opportunity becomes clear to make investments in comparatively-resilient property in the US (national resilience and local resilience) before market values accurately reflect environmental risk (Pagourtzi, 2003. UCS, 2018). This section has aspects of informed real estate speculation based on the most current scientific research into climate change and its projected impact on the United States, however, it should not be taken as investment advice, and readers should consult their professional financial advisors before making large speculative investments in real estate.

The following section will outline a series of strategies for resilient real estate investment in the United States, with some already being widely adopted and others that have not been publicly reported on or studied to date in 2023. These strategies are informed by discussion of the spatial disparities of environmental change and real estate value, and represent potential responses for investors to consider depending on their geographic region and investor profile.

Resilient Cities and ‘Climate Havens’

Resilient cities, often called climate-haven cities, are those resilient US urban locations with low environmental risk, along with strong infrastructure and institutions, and the ability to attract migrants seeking stability in a time of changing environmental conditions. Locations that are seen to be more resilient, whether those perceptions are supported by evidence or not, are likely to attract people and capital, and areas seen as higher risk are likely to see outward flows of people and capital as a result of the instability rapid environmental change can bring. The majority of people and capital is concentrated in cities, and this is where a number of Resilient Real Estate Investment Strategies are likely to be implemented.

In terms of high risk cities, the strategies of buying, holding, and renting high-elevation land in low-elevation coastal cities is an obvious strategy for the short-term, and can be described as a *local-resilience strategy*, but the risk of that strategy grows with the risks to the overall market. For long-term, stability-focused investors, including the largest institutions, wealthiest private individuals, and the sovereign wealth funds of nations, commercial real estate in the largest urban markets are generally the asset of choice. The largest real estate investors, including large banking institutions, most often want the security of urban multifamily, office, hotels, and retail buildings, and land in the largest U.S. cities that are classically considered some of the most stable assets in the world. These assets rely on the stability of their market to retain their value and grow in value over time, so if a city has existential risks that will be extraordinarily difficult to overcome, both the direct impacts and the changing preferences of individuals and

institutions will harm the value of assets in those locations. Large institutions generally seek stability, and real estate in cities that can be expected to benefit from net inflows of people and capital due to their location will provide the economic security and growth potential investors of all types seek out.

The most resilient medium-sized cities in the United States include Buffalo, NY; Albany, NY; Burlington, VT; Duluth, MN; Ann Arbor, MI; Cleveland, OH; Madison, WI; and Boise, ID (Pogue, 2021. Malo, 2019. Opperman, 2011. Abrams, 2022). These cities are likely to take in large numbers of domestic migrants looking for safer and more sustainable living situations (Pogue, 2021. Malo, 2019. Opperman, 2011). Investors should seek to buy property in cities that are projected to increase in population due to migration associated with environmental change. Many of these cities have seen a major population decline since the era of industrialization, so real estate values are low in an environment of excess supply and low demand. With climate change, that situation is likely to flip, and with a rising population generally comes rising property values. Those investors that make early speculative investments could see substantial returns over the next ten to twenty years. Many other factors will influence these cities as well, but the major trends of urbanization, and now, deglobalization, are likely to further influence movement to these cities.

An urban resilient investment strategy targeting local disparities in sea level rise vulnerability is to buy the highest elevation land in a coastal city at low elevation. This strategy would target the real estate with the lowest vulnerability to flooding which is a real estate value proposition in cities where the majority of property faces significant

flood risk. This strategy carries significant risk, as an investor will need to sell out of their position before the city's real estate values overall collapse under the weight of lost tax revenue and failing services. This strategy could be described as a form of 'disaster capitalism' because it specifically targets limited critical resources within potential disaster areas to maximize profits, in a similar way with the freshwater investment strategy (Klein, 2009). Examples of cities with extreme SLR-risk neighborhoods include Miami, New Orleans, Houston, Jersey City, Tampa, NYC, Boston, and many more (NOAA, 2021. UCS, 2018). This is one of the most expensive, risky, and amoral investment strategies of the four examples I will discuss, but with the fastest return on investment. This strategy is likely to be implemented after a major disaster when prices are lower and when real estate investors have been forced to consider environmental risk. This sort of high-risk/high-reward speculation in disaster areas can be considered a form of disaster capitalism, also known as profiting off of a disaster, however, prioritizing resilience in home buying and investment decisions should be considered basic logical investment analysis in 2023.

Resilient Rural Land

Quality natural land – including land with sustainable topsoil, forests, ecosystem services, freshwater resources, and bucolic scenes – is a limited, and declining resource in the United States. Natural places with limited development are becoming even rarer by the year, as more natural land is degraded beyond repair by environmental change.

The value Americans place on fresh air, clean water, and bucolic scenes is likely to increase as all three become more rare. The supply of resilient land is declining, from

development, wildfires, and insects, and the demand for it is increasing, as Americans are further and further removed from the natural scenery and smells that humans are hardwired to find happiness in. Evidence for an increased demand for nature from Americans became clear during the coronavirus pandemic, when workers were given the freedom of mobility through teleworking, and Americans sought out rural communities close to quality natural resources in record numbers, driving up the price of real estate in those exurbs and rural vacation towns to all-time highs (Dimke, 2021).

Those locations that grew in demand and population during the pandemic, are often natural retreats from the normal city or suburban lifestyle that many Americans were able to seek during the pandemic (Dimke, 2021. Rosalky, 2020). Some of these towns are resilient locations with a level of services and activities that will attract wealthy migrants looking to get away from cities and suburbs and live near nature while working remotely (Rosalky, 2020). The towns that had a spike in demand for housing, and subsequent price increases during the Pandemic, are likely receiver locations for future migrants seeking environmental security, and natural beauty.

For investors targeting resilient rural land, investments are most likely to be made within the Great Lakes region, the Northeast, and the Pacific Northwest. In each of these regions, land can be found for under \$1,000 per acre, and compare that to an expensive condo in the same region that can cost \$1,000 per square foot (Zillow.com, 2022).

Another potential rural land investment strategy, let's call the 'borderlands' strategy, is to invest in land that falls near the junction points between the US and Canada (Burlington, VT - Montreal, Canada. Buffalo, NY - Toronto, Canada). In a less stable

world, the flows of goods and people between the US and Canada could be expected to increase - due to the geographic proximity allowing for local supply chains, more resilient and sustainable for those resources and products that can be produced at home -, and lead to an increase in jobs and population in the borderlands region between Buffalo, New York and Toronto, Canada, as well as the regions between Burlington, Vermont and Montreal, Canada, and between Seattle, Washington and Vancouver, Canada. These regions also happen to be some of the most resilient places in the United States and are likely to see some benefits from warming temperatures leading to longer growing seasons and less harsh winters (Shaw, 2021. Pogue, 2021. First Street Foundation, 2021).

This leads us into the next potential strategy, that we will call the ‘resilient agriculture’ strategy (a.k.a. Future Farmland) which targets productive agricultural land that is resilient to environmental change. The farmland of today will not necessarily be the farmland of tomorrow because agriculture productivity is dependent on the soil quality, climate and precipitation, and other environmental conditions that are changing. Increasing temperatures, changing precipitation patterns, expanding insect habitats, larger wildfires, topsoil erosion, and limited freshwater will change where crops can be grown traditionally in the United States (Lin, 2011. Kearney, 2014). While there are countless adaptations within the agricultural sector to prolong the productivity of vulnerable farmland, these adaptations can be costly if they are to overcome nature. Farmland with reliable freshwater resources and moderate temperatures is more resilient than farmland in the hot and dry parts of the US, and farmland in locations that are too cold but projected to warm are likely to see increases in value as the growing seasons extend. This

represents an opportunity for real estate investment and agricultural investment in the most resilient food producing regions of the United States.

The freshwater-rights investment strategy, which was introduced in the previous section as a strategy that is already being implemented in the American West, targets properties with strong water rights in regions with limited freshwater resources. This strategy can target agricultural land in places considered nationally resilient in the US, similar to the resilient agriculture strategy, but with more opportunity for profit in locations with comparative resilience, driven by a comparative freshwater advantage. In areas where agriculture is the dominant industry and water resources are limited, those with access and rights to water can sell that water or use it themselves, and see their property values rise in comparison to the devaluation of water-poor lots nearby (Lin, 2011. Bendix, 2018. Kuwayama, 2019. Kearney, 2014). Reliable, affordable water is key to the profitability of a farm. One year, or a few years, of limited water can push both traditional farms and corporate farms into bankruptcy. This strategy can be implemented in several ways, including by buying property with significant water access/rights in areas with water scarcity. Energy production and manufacturing processes often require massive amounts of water, so agriculture producers must compete with other corporate interests for water (Kearney, 2014. Fishman, 2012). Several large institutional investors have already started to pour capital into properties with comparative water resilience, including the money manager for the Harvard University endowment (Bendix, 2018. Fishman, 2012). People need water to drink, and if there's not enough to drink and use at home, then there surely isn't enough for large-scale conventional agriculture, energy, and

manufacturing processes (Lin, 2011. Kwayana, 2019. Grasham, 2021, Fishman, 2012).

The demand for freshwater is increasing while the supply of easily available freshwater is declining, leading to an investment opportunity.

Another rural resilient land investment strategy is to target limited mineral resources that are available in the United States. Rare earth minerals and metals are already being targeted by major corporations in the United States and around the world as part of the global competition to secure the raw materials for the energy transition that is occurring. This leads to the opportunity of securing land with resources that will be increasingly demanded for decades as the economy transitions from dependence on fossil fuels to a dependence on the rare earth materials that solar panels, wind turbines, lithium batteries, and electric vehicles require for production.

Conclusion

Due to the experienced impacts and forward projections of environmental change on real estate, the uneven impacts across the nation, and the fixed nature of real estate, individual property owners as well as the national real estate economy are put at risk. For certain vulnerable locations, it is a matter of time before properties are devalued to accurately account for changing environmental risks. It is difficult to predict when a downward market adjustment will occur – which could be a rapid change or a slow trickle – meaning there could be multiple up/down cycles in the real estate markets before severe devaluations begin and prices begin to accurately reflect inherent risks (Hino and Burke, 2021. Boland et al., 2022. Pogue, 2021). It is also difficult to predict how individuals, businesses, and governments will react to increasing environmental risk.

Most likely the reactions will vary by heavily by location, the level of risk faced, and the resources available to adapt. The adaptations that are needed to secure the most vulnerable locations in the United States will require billions of dollars, overwhelming public support, cooperation between governments, and individuals, businesses and governments prioritizing resilience (Graasham, 2021. Bendell, 2020). It is more likely that locations with extreme risks, limited resources, and rising populations will struggle to keep quality of life and economic opportunity at stable levels over the long term, leading to changes in migration patterns, with dramatic impacts on real estate value.

The impacts of projected environmental change are not currently accounted for in the pricing, valuation, and underwriting of real estate in most U.S. locations, representing a major risk to the economic security of individuals and the nation (Gourevitch, et al., 2023. Hino and Burke, 2021). This paper is meant to inform individuals, communities, businesses, and governments on the environmental risks they should consider in all real estate decisions, and potential resilient real estate strategies to adapt to those risks. While changing environmental risks represent a major threat to the financial security of many property owners and the national economy, there is a potential opportunity in this crisis for investors to capitalize on environmental change using a resilient real estate investment strategy, targeting properties that are locally-resilient and nationally-resilient.

WORKS CITED

- Abrams, A. (2022). *Climate change risks get the attention of real estate investors*. The New York Times. April 2022.
<https://www.nytimes.com/2022/04/19/business/climate-change-flooding-developers.html>
- Ambrosio, N. (2019). *Assessing Local Adaptive Capacity to Understand Corporate and Financial Climate Risks*. FourTwentySeven. Jan 2019.
- Bakke, G. (2017). *The Grid: The Fraying Wires Between Americans and Our Energy Future*. Published in print in 2017.
- Boland, B., Levy, C., Palter, R., Stephens, D. (2022). *Climate Risk and Opportunity for Real Estate*. Mckinsey and Company. Feb 4th, 2022.
<https://www.mckinsey.com/industries/real-estate/our-insights/climate-risk-and-the-opportunity-for-real-estate>
- Beck, J., Lin, M. (2020) *Impact of Sea Level Rise on Real Estate Prices in Coastal Georgia*. The Review of Regional Studies. Vol 49, 2020. The impact of sea level rise on real estate prices in coastal Georgia
- Benjamin, K., Mulder, P. (2020). *Housing Markets, Mortgage Lending, and Sea Level Rise*. National Bureau of Economic Research. October 2020.
<https://www.nber.org/papers/w27930>
- Bendell, J., Rupert, R (2018). *Deep Adaptation: Navigating the Realities of Climate Chaos*. July 2018. Published in print by Polity in 2018.
- Bendix, A. (2018). *Harvard has quietly bought \$305 million worth of California Vineyards, the water rights could be even more valuable*. December 17th, 2018.
<https://www.businessinsider.com/harvard-california-vineyards-water-rights-2018-12>
- Brenkert, H., Champ, P., Flores, N., (2005). *Mitigation of wildfire risk by homeowners*. Res. Note RMRS-RN-25. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 9 p.
- Bin, O., & Kruse, J. B. (2006). *Real estate market response to coastal flood hazards*. Natural Hazards Review, 7(4), 137-144.
- Bierbaum, R., Smith, J.B., Lee, A. et al. (2013) *A comprehensive review of climate adaptation in the United States: more than before, but less than needed*. Mitigation and Adaptation Strategies for Global Change 18, 361–406, 2013). <https://doi.org/10.1007/s11027-012-9423-1>

- Brunetti, Celso, Benjamin Dennis, Dylan Gates, Diana Hancock, David Ignell, Elizabeth K. Kiser, Gurubala Kotta, Anna Kovner, Richard J. Rosen, and Nicholas K. Tabor (2021). *Climate Change and Financial Stability*. Washington: Board of Governors of the Federal Reserve System, March 19, 2021, <https://doi.org/10.17016/2380-7172.2893>.
- Carrey, J. (2020). *Managed Retreat increasingly seen as necessary in response to climate change's fury*. *Journal of Economic Sciences*.117 (24) 13182-13185. May 27th, 2020. <https://doi.org/10.1073/pnas.2008198117>
- Clayton, J. et al. (2020). *Resilient Real Estate*. *Journal of Portfolio Management*. Jim Clayton, Frank J. Fabozzi, S. Michael Giliberto, Jacques N. Gordon, Youguo Liang, Greg MacKinnon and Asieh Mansour. <https://jpm.pmr-research.com/content/early/2021/07/26/jpm.2021.1.277>
- Clayton, J., Devaney, S., Sayce, S., Van de wetering, J. (2021). *Climate Risk and Commercial Property Value: a review and analysis of the literature*. Clayton, 2021. https://www.unepfi.org/wordpress/wp-content/uploads/2021/08/Climate-risk-and-real-estate-value_Aug2021.pdf
- Crotty, J. (2009) *Structural Causes of the Global Financial Crisis*. *Cambridge Journal of Economics*, Volume 33, Issue 4, July 2009, Pages 563–580, <https://doi.org/10.1093/cje/bep023>
- Coaffee, J., Lee., P. (2016) *Urban Resilience: Planning for Risk, Crisis, and Uncertainties*. Published in Print by Palgrave Macmillan in the U.K. 2016.
- Cupal, M. (2015). *Flood risk as a price-setting factor in the market value of real property*. *Procedia Economics and Finance*, 23, 658-664.
- Davis, J. (2017). *The Gulf: The Making of an American Sea*. 2017. Published in print by Liveright Publishing.
- Duca, J., Murphy, A. (2021). *Why house prices surged as the Covid-19 Pandemic took hold*. Dallas Federal Reserve Bank. December 28th, 2021. <https://www.dallasfed.org/research/economics/2021/1228.aspx>
- Desmond, M. (2016). *Evicted: Poverty and Profit in the American City*. Published in March, 2016. Crown Publisher.
- Dimke, C., Lee, M., Bayham, J. (2021). *Covid-19 and the Renewed Migration to the Rural West*. *Western Economics Forum Journal*, Spring 2021, Vol. 19, Iss. 1. <https://waeaonline.org/wp-content/uploads/2021/06/WEF-Volume-19-Issue-1-COVID-19-FINAL.pdf#page=89>

- Eichholtz, P., Steiner, E., & Yönder, E. (2019). *Where, When and How Do Sophisticated Investor Respond to Flood Risk?*. Cornell University.
- Eichholtz, P. Kok, N, Quigley. J. (2013). *The Economics of Green Building*. *The Review of Economics and Statistics*: 2013; 95 (1): 50–63. doi: https://doi.org/10.1162/REST_a_00291
- FEMA, (2021). *National Natural Hazard Risk Index*. Federal Emergency Management Agency. Updated 2021. <https://www.fema.gov/flood-maps/products-tools/national-risk-index/overview>
- FEMA, (2015). *Flood Insurance: How It Works*. *FEMA.gov*, Mar. 2015. www.fema.gov/media-library-data/1427811288492-36fb55e74d14c318db2996580527d131/Flood_Insurance_How_It_Works.pdf.
- FEMA, (2021). *FEMA Risk Rating 2.0 is Equity in Action*. April 2021. https://www.fema.gov/sites/default/files/documents/fema_rr-2.0-equity-action_0.pdf
- First Street Foundation, (2020). *First National Flood Risk Assessment*. First Street Foundation. June, 2020. https://assets.firststreet.org/uploads/2020/06/first_street_foundation__first_national_flood_risk_assessment.pdf
- Fishman, C. (2012). *The Big Thirst: The Secret Life and Turbulent Future of Water*. February, 2012. Published in print.
- Fox, J. (2013). *What we have learned from the Financial Crisis*. *Harvard Business Review*. November, 2013. <https://hbr.org/2013/11/what-weve-learned-from-the-financial-crisis>
- Fujita, M., Krugman, P., Venables, A. (2001) *The Spatial Economy: Cities, Regions, and International Trade*. MIT Press paperback edition published in 2001.
- Gibson, A. (2019). *Climate Change for Individuals Experiencing Homelessness: Recommendations for Improving Policy, Research, and Services*. *Journal of Environmental Justice*. 2019, 12:4, pg. 159-163.
- GBCI, (2020) *From Risk to Resilience: Building a Healthier, more resilient future*. Published 2020. Accessed online January 2023. https://www.usgbc.org/sites/default/files/2022-04/GBCI_Resilience-Report-Update_DL_v5_0.pdf
- Getis A., Getis, J. (1966) *Christaller's Central Place Theory*. *Journal of Geography*, 65:5, 220-226, DOI: 10.1080/00221346608982415

- Gourevitch, J.D., Kousky, C., Liao, Y., et al., (2023). *Unpriced climate risk and the potential consequences of overvaluation in US housing markets*. *Nature Climate Change*. (2023). <https://doi.org/10.1038/s41558-023-01594-8>
- Grasham, C.F., Calow, R., Casey, V. et al. (2021) *Engaging with the politics of climate resilience towards clean water and sanitation for all*. *npj Clean Water* 4, 42, 2021. <https://doi.org/10.1038/s41545-021-00133-2>
- GRESB, (2021). *Resilience Management: A Multifaceted Approach to Real Estate Investing*. Global Real Estate Sustainability Benchmark. June 23, 2021. <https://www.gresb.com/nl-en/resilience-management-a-multifaceted-approach-to-real-estate-investing/>
- GRESB, (2021) *The Evolution of Real Asset Resilience*. Global Real Estate Sustainability Benchmark. March 2021. <https://gresb.com/nl-en/insights/the-evolution-of-real-asset-resilience/>.
- GBCI, (2021). *Rating Guidelines for Resilient Design and Construction, RELi 2.0*. Feb 2021. Green Businesses Certification Inc. <https://www.gbci.org/reli>
- Hino, M., Burke, M. (2021). *The effect of information about climate risk on property values*. Cornell University. Published April 20th, 2021. <https://doi.org/10.1073/pnas.2003374118>
- IPCC, (2022): *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Lössche, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press. https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_SummaryForPolicymakers.pdf
- Johnson, et al, 2019. *A Benefit-Cost Analysis of Floodplain Acquisition for US Flood Damage Reduction*. Published in *Nature* in 2019. <https://www.nature.com/articles/s41893-019-0437-5>
- Kearney, M. S., Harris, B. H., Hershbein, B., Jácome, E., & Nantz, G. (2014). *In times of drought: Nine economic facts about water in the United States*. The Hamilton Project, 1-28. <https://www.brookings.edu/wp-content/uploads/2016/06/nineeconomicfactsaboutuswaterkearneyharris.pdf>
- Keller, M (2017). *Outdated and Unreliable: FEMA's Flood Maps Put Homeowners at Risk*. Bloomberg, 6 Oct. 2017, www.bloomberg.com/graphics/2017-fema-faulty-flood-maps/.

- Keys, B., Mulder, P. (2020) *Housing Markets, Mortgage Lending, and Sea Level Rise*. National Bureau of Economic Research. October 2020.
<https://www.nber.org/papers/w27930>
- Klein, N. (2007) *The Shock Doctrine: The Rise of Disaster Capitalism*. Published in Print by Knopf Canada in 2007.
- Knowlton, K., Rotkin-Ellman, M., Geballe, L., Max, W., Solomon, G., (2011). *Six Climate Change-Related Events in the United States Accounted for about \$14 billion in Lost Lives and Health Costs*. Health Affairs, vol. 30, no. 11.
<https://doi.org/10.1377/hlthaff.2011.0229>
- Kousky, C., Kunreuther, H., LaCour-Little, M. (2020). *Flood Risk and the U.S. housing market*. Journal of Housing Research: Natural Disasters and the Housing Market. Vol 29, November 2020.
<https://www.tandfonline.com/doi/full/10.1080/10527001.2020.1836915>
- Krueger, A (2018). *Climate Change Insurance: Buy Land Somewhere Else*. New York Times. November 2018. <https://www.nytimes.com/2018/11/30/realestate/climate-change-insurance-buy-land-somewhere-else.html>
- Kulp, S.A., Strauss, B.H (2019). *New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding*. Nature Communications 10, 4844. 2019. <https://doi.org/10.1038/s41467-019-12808-z>
- Kuwayama, Y., Thompson, A., Bernknopf, R., Zaitchik, B. and Vail, P. (2019), *Estimating the Impact of Drought on Agriculture Using the U.S. Drought Monitor*. American Journal of Agricultural Economics, 101: 193-210.
<https://doi.org/10.1093/ajae/aay037>
- Lee, N. (2021). *Here's why the ultra-wealthy like Bill Gates and Thomas Perterffy are investing in US farmland*. CNBC. August 20th, 2021.
<https://www.cnbc.com/2021/08/20/heres-why-the-ultra-wealthy-like-bill-gates-investing-to-farmland.html>
- Lin, B. (2011) *Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change*, BioScience, Volume 61, Issue 3, March 2011, Pages 183–193, <https://doi.org/10.1525/bio.2011.61.3.4>
- Lovett, J. (2017). *Moving to higher ground: protecting and relocating communities in response to climate change*. Vermont Law Review., 42, 25.
<http://lawreview.vermontlaw.edu/wp-content/uploads/2018/02/04-Lovett.pdf>
- Lustgarten, A. (2020) *The Great Climate Migration*. The New York Times. In collaboration with ProPublica and The Pulitzer Center.
<https://pulitzercenter.org/sites/default/files/inline-images/jEu86t17dIVE7rPSH1JU9CYyVvZ8EZZKIfTzWyIVFCXzLHT62m.pdf>

- Luber, G., McGeehin, M. (2008) *Climate Change and Extreme Heat Events*. Am J Prev Med 2008;35(5):429 – 435) Published by Elsevier Inc. on behalf of the American Journal of Preventive Medicine. <https://doi.org/10.1016/j.amepre.2008.08.021>
- Mahoney, A. (2022). *Why Renters are Uniquely Vulnerable to Climate Disasters*. Grist.org. January, 25, 2022. <https://grist.org/housing/climate-disasters-american-housing-crisis-renters/>
- Meadows, D., Randers, J., Meadows, D. (2004) *Limits to Growth: The 30-year Update*. Published in 2004 by Chelsea Green Publishing. Limits to Growth was first published in 1972 at MIT.
- Malo, S. (2019). *Cool U.S. cities prepare as future 'havens' for climate migrants*. Reuters. Apr 6, 2019. <https://www.reuters.com/article/us-usa-climatechange-migration/cool-u-s-cities-prepare-as-future-havens-for-climate-migrants-idUSKCN1RI061>
- Manhertz, T. (2022). *US housing market has doubled in value since the 2008 great recession, gaining \$6.9 trillion in 2021*. Zillow.com. 2022 <https://www.zillow.com/research/us-housing-market-total-value-2021-30615/>
- McLeman, R. (2015). *Climate and Human Migration*. Published in print by Cambridge University Press in 2015.
- Meyer, R. (2019). *How Climate Change Could Trigger the Next Global Financial Crisis*. The Atlantic, Atlantic Media Company, 1 Aug. 2019, www.theatlantic.com/science/archive/2019/08/how-fed-could-fight-climate-change-adam-tooze/595084/
- Miranda, H. Stewart, S. Volker, C. Radeloff, R., Hammer, B., Alexandre, P. (2015). *Adapting to Wildfire: Rebuilding After Home Loss*. Society & Natural Resources, 28:8, 839-856, DOI: 10.1080/08941920.2015.1014596
- Miller, R. G., & Pinter, N. (2022). *Flood risk and residential real-estate prices: Evidence from three US counties*. Journal of Flood Risk Management, 15(2), e12774.
- Motta, M., Ralston, R., Spindel, J., (2021) *A Call to Arms for Climate Change? How Military Service Member Concern About Climate Change Can Inform Effective Climate Communication*. Environmental Communication 15:1, 85-98, DOI: 10.1080/17524032.2020.1799836
- NACO. (2022) *Building Wildfire Resilience: A Land Use Toolbox for County Leaders*. National Association of Counties. <https://www.naco.org/resources/building-wildfire-resilience>

- Nalau, J., Verrall, B. (2021). *Mapping the evolution and current trends in climate change adaptation science*. Journal of Climate Risk Management, Vol. 32, 2021, 100290. <https://doi.org/10.1016/j.crm.2021.100290>
- National Law Review, (2019). *National Flood Insurance Program Info and Pitfalls*. National Law Review, Volume IX, Number 100. <https://www.natlawreview.com/article/what-my-flood-policy-doesn-t-cover-flood-damage-and-other-pitfalls-nfip-flood>
- Neuman, S., (2022) *One Florida community built to weather hurricanes endured Ian with barely a scratch*. October 6th, 2022. Accessed online 10/7/22. <https://www.npr.org/2022/10/05/1126900340/florida-community-designed-weather-hurricane-ian-babcock-ranch-solar>
- Nikolaidis, N (2011). *Human Impacts on Soil: Tipping points and knowledge gaps*. Department of Environmental Engineering, Technical University of Crete, 73100 Chania, Greece. <https://doi.org/10.1016/j.apgeochem.2011.03.111>
- NOAA, (2014), *Climate Resilience Toolkit Guide*. National Oceanic and Atmospheric Administration. First developed in 2014, updated in 2021. <https://toolkit.climate.gov/steps-to-resilience/explore-hazards>
- Okmyung, B., Poulter, B., Dumas, C., Whitehead, J. (2010). Measuring the Impacts of Sea-Level Rise on Coastal Real Estate: A Hedonic Property Model Approach. December, 2010. Journal of Regional Science, Vol 51, Issue 4, pg. 751-767. <https://doi.org/10.1111/j.1467-9787.2010.00706.x>
- Opperman, J. (2011). Which cities can best adapt to climate change? Grist.org. Jun 23, 2011. <https://grist.org/climate-change/2011-06-23-which-cities-adapt-most-resilient-to-global-warming/>
- Pagourtzi, E., Assimakopoulos, V., Hatzichristos, T. and French, N. (2003) *Real estate appraisal: a review of valuation methods*. Journal of Property Investment & Finance, Vol. 21 No. 4, pp. 383-401. <https://doi.org/10.1108/14635780310483656>
- Petit, F. D. P., et al. (2013). *Resilience measurement index: An indicator of critical infrastructure resilience*. No. ANL/DIS-13-01. Argonne National Lab.(ANL), Argonne, IL (United States), 2013.

- Piguet, E., Pécouid, A., Guchteneire, P. (2011). Migration and Climate Change: An Overview, *Refugee Survey Quarterly*, Volume 30, Issue 3, September 2011, Pages 1–23, <https://doi.org/10.1093/rsq/hdr006>
- Pogue, D. (2021). *How to Prepare for Climate Change: A Practical Guide to Surviving the Chaos*. Pg. 39-89, ‘Where to Live’, 89-139, ‘How to Build’, 163-193, ‘Where to Invest’. Published in print by Simon and Schuster Books in 2021.
- Poorvu, W., Cruikshank, J. (1999) *The Real Estate Game: The Intelligent Guide to Decision Making and Investment*. First Published by Simon & Schuster in 1999.
- Reisner, M. (1986). *Cadillac Desert: the American West and its Disappearing Water*. Penguin Publishing Group. 1986.
- Richardson, B. (2021). *Housing Market Gains More Value in 2020 than in any year since 2005*. Forbes. Jan 26, 2021.
<https://www.forbes.com/sites/brendarichardson/2021/01/26/housing-market-gains-more-value-in-2020-than-in-any-year-since-2005/?sh=1ac4dce94fe0>
- Rosalky, G. (2020). *Zoom Towns and the New Housing Market for the 2 Americas*. NPR.org. September 8th, 2020.
<https://www.npr.org/sections/money/2020/09/08/909680016/zoom-towns-and-the-new-housing-market-for-the-2-americas>
- Roberts, S., Wood, A. (2011) *Economic Geography: Places, Networks, and Flows*. Published in 2011 by Routledge in New York. Print.
- Schipper, E.L.F (2022). *Catching maladaptation before it happens*. Nature Climate Change, 12, 617–618 2022. <https://doi.org/10.1038/s41558-022-01409-2>
- Scism, L., Campo-Flores, A. (2021). *Insurance costs threaten Florida real estate boom*. Wall Street Journal. Published online April 25th, 2021.
<https://www.wsj.com/articles/insurance-costs-threaten-florida-real-estate-boom-11619343002>
- Shaw, A., Lustgarten, A. (2020). *New Climate Maps show a transformed United States*. ProPublica - Climate Migration. Sept 15, 2020.
<https://projects.propublica.org/climate-migration/>
- Sheldon, B.L. (2019). *Fearless: Real Estate Investing in the Era of Climate Change*. Published by Moments Count Press in 2019.
- Shaxson, N. (2011). *Treasure Islands: uncovering the damage of offshore banking and tax havens*. Published by St. Martin’s Press, LLC in the United States in 2011.

- Siders, A. R. (2019). *Managed retreat in the United States*. *One Earth* 1, 216–225. 2019. <https://doi.org/10.1016/j.oneear.2019.09.008>
- Sigaud, L. (2018). *Fixing the National Flood Insurance Program*. The Hill. <https://thehill.com/opinion/finance/416301-fixing-the-national-flood-insurance-program/>
- Smith, A. (1776). *The Wealth of Nations*. Published 1776. Oxford, England.
- Smith, A. B. (2020). *2010-2019 a Landmark decade of U.S. billion-dollar weather and climate disasters*. Climate.gov. Jan 8, 2020. <https://www.climate.gov/news-features/blogs/beyond-data/2010-2019-landmark-decade-us-billion-dollar-weather-and-climate>
- Stein, S. (2019). *The Housing Crisis and the Rise of the Real Estate State*. *New Labor Forum*, 28(3), 52–60. <https://doi.org/10.1177/1095796019864098>
- Sweet, W., et al (2022). B.D. Hamlington, R.E. Kopp, C.P. Weaver, P.L. Barnard, D. Bekaert, W. Brooks, M. Craghan, G. Dusek, T. Frederikse, G. Garner, A.S. Genz, J.P. Krasting, E. Larour, D. Marcy, J.J. Marra, J. Obeysekera, M. Osler, M. Pendleton, D. Roman, L. Schmied, W. Veatch, K.D. White, and C. Zuzak. *Global and Regional Sea Level Rise Scenarios for the United States: Up- dated Mean Projections and Extreme Water Level Probabilities Along U.S. Coastlines*. NOAA Technical Report NOS 01. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD. <https://oceanservice.noaa.gov/hazards/sealevelrise/noaa-nos-techrpt01-global-regional-SLR-scenarios-US.pdf>
- Solnit, R. (2009) *A Paradise Built in Hell*. Published in print in 2009 by Viking.
- Tollefson, J. (2018). *IPCC says limiting global warming to 1.5 [degrees] C will require drastic action*. *Nature*, 562(7726), 172-174. <http://dx.doi.org/10.1038/d41586-018-06876-2>
- Tracy, B., Bast, B., Spinder, C. (2023). *New York Investors snapping up Colorado River water rights, betting big on an increasingly scarce resource*. CBS News. January 31, 2023. <https://www.cbsnews.com/news/new-york-investors-snapping-up-colorado-river-water-rights-betting-big-on-an-increasingly-scarce-resource/>
- UCS. (2018). *Underwater*. Union of Concerned Scientists, 18 June 2018, www.ucsusa.org/resources/underwater
- U.S. Congress. (2010). *Dodd-Frank Wall Street Reform and Consumer Protection Act*. 111th Congress - House Bill 4173. <https://www.congress.gov/bill/111th-congress/house-bill/4173/text>

- U.S. Department of Treasury. (2022). *2021 Federal Government Spending*. America's Finance Guide - Datalab. USASpending.gov. 2022.
<https://datalab.usaspending.gov/americas-finance-guide/spending/>
- U.S. Department of Defense. (2021) *Department of Defense Climate Risk Analysis*. Published October 2021. Produced for the National Security Council.
- Veridinez, D. (2021). *USGBC to focus on driving resilience strategies through its LEED green building program*. LEED. USGBC. Dec 2021.
<https://www.usgbc.org/articles/us-green-building-council-announces-reli-system-be-managed-and-operated-institute-market>
- Vespa, J. (2018). *The US Joins Other Countries with Large Aging Populations. The Graying of America: More Older Adults than Kids by 2035*. US Census Bureau. Mar 13, 2018. <https://www.census.gov/library/stories/2018/03/graying-america.html>
- Warren-Myers, G. (2012). *The value of sustainability in real estate: a review from a valuation perspective*. Journal of Property Investment & Finance, Vol. 30 No. 2, pp. 115-144. <https://doi.org/10.1108/14635781211206887>
- Warren-Meyers, G., Hurliman, A. (2022). *Climate Change and Risk to Real Estate. A Research Agenda for Real Estate*, ch. 8, pg. 139-164. March 8th, 2022.
<https://doi.org/10.4337/9781839103933>
- Water Asset Management. *Corporate Website Homepage*. <https://waterinv.com/home>. Headquartered in Manhattan, NYC. Accessed February 1st, 2023.
- Westling, L. (2022). *Deep History, Climate Change, and the Evolution of Human Culture*. Cambridge University. Published by the Cambridge University Press in 2022. doi:10.1017/9781009257343
- Winchester, S. (2021) *Land: How Hunger for Ownership Shaped the Modern World*. Publisher: Harper. Jan 19th, 2021.
- Worland, J. (2021). *The Climate Real Estate Bubble: Is the US on the Verge of Another Financial Crisis*. Time Magazine. April 19, 2021.
<https://time.com/5953380/climate-housing-crisis/>
- Wuebbles, D. et al, (2017). Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, B. DeAngelo, S. Doherty, K. Hayhoe, R. Horton, J.P. Kossin, P.C. Taylor, A.M. Waple, and C.P. Weaver, 2017: Executive summary. In: *Climate Science Special Report: Fourth National Climate Assessment, Volume I*. U.S. Global Change Research Program, Washington, DC, USA, pp. 12-34, doi: 10.7930/J0DJ5CTG.

CURRICULUM VITAE – [REDACTED]

