Lines (57° 59´N, 7° 16´W) by Finnish artists Pekka Niittyvirta & Timo Aho, “The installation explores the catastrophic impact of our relationship with nature and its long-term effects,” “The work provokes a dialogue on how the rising sea levels will affect coastal areas, its inhabitants and land usage in the future.”

Property Value in an Era of Climate Change

by
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Submitted to OCAD University in partial fulfillment of the requirements for the degree of
Master of Design in Strategic Foresight and Innovation
Toronto, Ontario, April, 2019

Author's Declaration:

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Abstract:

Climate change impacts are affecting property values across the North American continent. Property losses from both insurable and uninsurable climate hazard related sources are increasing annually. This study aims to discover property value impacts across the market and to understand future impacts of climate hazard on North American real estate values.

Property value impacts of climate-risk are evaluated with a broad market approach to understanding the ways site improvement losses (buildings), and property (land) devaluation occur in relations to increases in catastrophic loss, as a result of climate-risk. The research points to urgent need for innovation in the housing sector. The research reveals patterns that demand industry and government attention and which demonstrate that the home owner is the most vulnerable stakeholder. Recommendations are offered as next steps; recommendations are made for helping home owners adapt to emerging climate-risk challenges.

Key words: climate change, adaptation, property valuation, climate-risk index, real estate, sea-level, pluvial, fluvial, storm surge, wildfire, drought, resilience, lending, home owner, Abandoning Atlantis, death taxes and climate change, REC Index, real estate climate index, real estate climate-risk index.

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Thanks to close friends who took the time to read and comment in an effort to create an output with clarity of ideas and ease of comprehension. Thanks for friends and family for encouragement and support.

Dedication: Prepared for Property Owners Everywhere

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Introduction

Climate Change, Property Risk and its Impact on Market Valuation

Climate Change is an undisputed science. The potential variability of the timing of impacts is yet to be seen, however the frequency and severity of climate change-risk is increasing measurably in property damage and quality of life impacts to populations in North America and globally (Aitsi-Selmi, A., Egawa, S., Sasaki, H., Wannous, C., & Murray, V. 2015; Barron, S., Canete, G., Carmichael, J., Flanders, D., Pond, E., Sheppard, S., & Tatebe, K. 2012; Dai, A. 2012; Elsner, J. B., Fricker T., & Schroder, Z. 2019; Feltemate, B. and Thistlethwaite, J. 2012.; Global Warming of 1.5°C: 2018; Hallegatte, S., Hourcade, J.C., & Ambrosi, P. 2007; Karl, T.R., J. T. Melillo, & T. C. Peterson 2009; Keiter, R., B.2014 2012; Kelman, I.2015; Mills, E. 2009; Moser, S. C. 2005; Schlenker, W. Hanemann M., & Fisher, A. C., 2007; U.S. Global Change Research Program 2014; Warren, F. J, & Lemmen, D. S., 2014; Westerling, A. L., H. G. Hidalgo, D. R. Cayan, & T. W. Swetnam 2006; Williams, G. 2019,…).

Historic impacts of climate change on real estate values can be measured (Yeo 2003; Troy 2003; Eves and Wilkinson, 2014; Tobin & Montz 1994). The negative real estate value impacts of flood, wildfire, wind, sea-level rise and drought are significant.

The stakes are high for those who are likely to be impacted by climate-change. Understanding the risks and adapting to them is of paramount importance.

The value impacts are measurable in catastrophic losses to property from severe weather (Smith, A. B. 2018). Losses are also measurable by comparing the market value of a home, in an area before and after a major climate-related event. For example a home that catches fire due to wildfire is directly affected, a home across the street or down the road may be affected by reduced market demand due to proximity, sense of risk, or visibility of damage. Properties directly and indirectly affected can suffer significant market value loss. This study aims to examine trends in measured property-value-loss, including an examination of people's attitudes about property risk and a speculative look at property values and an era of climate change.

In North America real estate ownership is central to cultural status, personal well-being, upward mobility and wealth (Goodman, L., & Mayer, C., 2018). The motive for this study is to inform property owning North Americans with a heuristic (accessible understanding and instigation to action) for understanding the urgent need to respond to the growing property and wealth risks resulting from Anthropogenic Climate Change and related property devaluation. This study is targeted to help individual home and recreational property owners to understand the impacts of climate change to personal wealth, continuity of use, insurability, finance-ability and lasting value.

Damage to properties, temporary displacement of populations and climate-driven migration pose major challenges for housing systems (Pryce, G., & Chen, Y., 2011). Examining and making sense of value-impact-trends from past climatological events offers a reliable lens for examining present and future property value risk for homeowners. This is an area of growing concern to the quality of life and wealth of Canadian and American populations.

Unforeseen catastrophe is already part of the emergent world of property risk. The dynamic ecological systems that have been in relatively consistent balance on Earth for millions of years are now out of balance. Major ecological systems are collapsing, and the meteorological impacts will be felt broadly and unexpectedly. There is an increasing probability that statistically-unlikely meteorologically-catalyzed catastrophes will occur with greater frequency, and severity, across North America and around the world (Seneviratne, S. I., Nicholls, N., Easterling, D., Goodess, C. M., Kanae, S., Kossin, J., ... & Reichstein, M. 2012).

Central to real estate valuation regardless of individual preferences is a desire, when owning or renting for: 1) minimal disruption of use, and 2) maximum benefit of use. This is true if the property is a tenanted investment, recreational property or primary residence. Climate change is negatively impacting value, wealth and the insurable cost of risk. Real estate holdings may be modest, or ostentatious, but home is family, and is the centre point for the quality of life for people everywhere. North American's homes and cottages are our largest personal assets.

METHODOLOGY:

Trends from diverse academic perspectives reveal real estate value from climate-risk, as well as opportunity, in an era of climate change. Understanding property value fragility to devaluation from climate-risk is central to creating capacity to adapt. Increasing bodies of evidence demonstrate that changing weather patterns are affecting real estate of all types around the world. This study is particularly focused on implications to North American residential and recreational real estate values, especially those affected by Flood, Wind, Drought, Wildfire, and Sea-Level Rise. Property impacts related to unprecedented cold weather events, changing freeze thaw cycles, and geological events (earthquake & tsunami) are outside of the focus of this study but are important risk factors with significant impacts.

An examination of patterns in scientific climate-impact data by risk type offers an overview of the types of outcomes that are being felt from changing weather patterns across the continent. This evidences regional academic hedonic (a scientific method for valuing individual property characteristics such as location benefits and site improvements and component contributions to value) studies across North America and beyond provide a framework for understanding property valuation trends related to climate-risk. Review of research of home owner awareness of risk, and willingness to act to protect property is key to understanding market behaviour. Industry and academic sources in Canada, the United States and Europe provide a sense of the systemic and psychological barriers to property owners accepting and acting to protect at-risk property.

The framework for making sense of this research is the three horizon method (Sharpe, B., Hodgson, A., Leicester, G., Lyon, A., & Fazey, I., 2016). This framework allows for a time-based understanding of the research. The first horizon offers a view of present and past climate-risk. It offers a status-quo understanding of what has and is happening in North America related property devaluation due to climate-risk. In the second horizon we see clear examples of market innovation that is emerging to help mitigate climate-risk and property value impacts. Horizon two also illuminates marketplace points of resistance to change, within the real estate industry, the supply chain of services, and in homeowner awareness. The third horizon offers a perspective of preferred 2030 real estate market where property connected climate-risk is disclosed. By examining the research in three horizons a clear understanding of climate-risk impacts to homeowners today, positive market responses today, and future housing market are revealled. This offers a lens for the housing market to accelerate adaptation to emerging climate-value-risk-impacts.

Examining the dynamic system that represents the collision of housing value economics, emerging extreme weather patterns and unpredictability of never-seen-before catastrophic events, is not an exercise in actuarial study of recent historic market performance. It is not a proving of proven science. It is a reconciliation and perspective-setting lens which offers a view to real estate-based wealth impacts, opportunities and risks. It takes into account emerging realities of changing weather systems combined with measured direct value impacts on the homes and communities we live in, where our life savings are invested.

A Paradox of Property Risk Valuation

Real estate valuation is connected to a matrix of stakeholders, starting with the homeowner. The homeowner is proud of her home, and she invests in improving its value, while she uses the home. The insurer assures that if something bad happens the property is protected. The lender provides the homeowner with necessary funds, beyond the down payment, to own the property. The municipality provides services including water, storm and sewer, and is interested in preserving the conditions of a healthy tax base, including retention of property value. All of these stakeholders want the value of the home to increase. When we consider this home ownership perspective in the context of climate change a paradox of valuation emerges for those properties that are at risk.

Every player in the stakeholder supply chain has a vested interest in preservation of current real estate value. From the homeowner, lender, insurer, Realtor®, municipality, regional government, and even state and federal governments. Each participant has a vested interest in the retention and growth of property value. All players in the supply chain have a significant potential property value loss to be suffered from property devaluation as a result of disclosure of risk, or devaluation from a severe weather event. The potential also exists for properties with reduced climate change risk to be more positively valued. A paradox of valuation emerges because no player in the housing supply chain wants an asset to lose value. In this way no party wants to move first, toward disclosure of property risk and potential devaluation.

Insurers, are financially exposed to unprecedented risk from climate-risk patterns. Emergent industry practice shows that some properties with increased risk profiles can be uninsurable, or more costly to insure, with greater exemption of coverage. The disclosure of risk within the real estate sale cycle also appears precarious. Negative property value impacts affect the profitability of lenders via stranded and toxic mortgages (mortgages that are secured by unsellable or devalued assets or are abandoned by the borrower), homeowners via wealth erosion, Realtors(r) via decreased income and eroded brand trust, market shrinkage and increased liability potential. These impacts expose municipalities and senior level governments to liability from non-disclosure of infrastructure-failure-potential, known topographic vulnerability and meteorological data sharing. Municipalities that are at risk are likely to encounter decreased tax base, higher adaptation and recovery costs. The long term viability of some communities may be in question (Melillo, J. M. 2014). Rising losses are likely to create more demand for conventional forms of insurance, as well as new products such as weather derivatives and catastrophe bonds (Allen, F., & Yago, G. 2010; Economics, M. R., 2008)

Future real estate values need to be evaluated with humility. The complexity of extreme weather pattern impacts on property are coupled with market psychology, economic conditions and political stability; and diverse factors that shape the valuation conditions for local real estate markets. The dynamical system of housing economics, market psychology, and meteorological factors is mathematically complex. That said, climate change is negatively impacting property values in North America. Climate change impacts go well beyond “the butterfly effect” (Gleick, J., 2011) in impacting market value. Risk vulnerability is only beginning to be considered and understood by stakeholders (Stigge, B., 2015). It is this ‘new, never before considered’ matrix of variables that motivate property owners in an effort to understand the impacts of climate-risk on their personal real estate assets.

World politics, human rights, economic opportunity and quality of life indices have affected international demand for property in North American cities. Future real estate values will be impacted by climate and weather based risk vectors including individual property and connected infrastructure resilience, favourable weather conditions, unfavourable weather risk, and regional capacity to respond.

Additionally regional real estate values are tied to regional energy, infrastructure, hydrology, geology, and extreme weather events. The value of ecological services and the cost of insurable risk are important considerations as well. These complex details are not part of the common real estate marketing process, and require a sophisticated disclosure and market valuation mechanism.

There are additional resilience measures related to infrastructure, fuel and power networks, and economic downtime, which are significant compounding risk factors. These 'beyond the home" resilience measures are not extensively examined within this study, but are identified as important in creating regional resilience and disaster-responsiveness. Common examples include dykes, levees and seawalls.

Finally, there is a lot at stake with the emerging conversation about climate change impact on property valuation. How is awareness about emergent issues developed? Who is responsible for disclosure? How is the message tailored for maximum receptivity by the marketplace? If flood mapping is available how is the information released and disseminated? Should we protect the individual property owners who might suffer devaluation of property as a result of disclosure? How do we protect the home owner? Is it responsible to expropriate and relocate property owners located in high-risk locations? Who bears the cost of these transitions? What is the most Economically efficient path to resilience?

It is this complex system of variables that impact valuation and the disclosure of this knowledge that creates paradox of valuation. Without forthright disclosure of risk and its causal connection to climate change there persists a paradox of valuation, which is that the party in the supply chain with the most to lose is the home owner.

Overview of Categorical Climate Change Risk Impacts & Property Exposure Characteristics

Understanding climate-risk begins with understanding the the ways that property is damaged by changing weather and related impacts. This section provides an overview understanding of the scientific, meteorological, and geologic impacts of climate-risk. The goal of this section is to offer an understanding of the underlying conditions that are resulting in property damage.

Flooding

Trends in Flood Magnitude

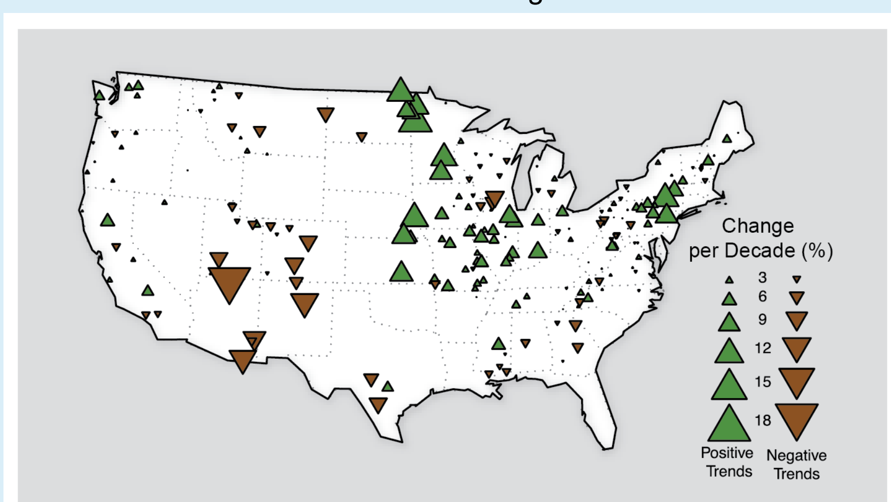


Figure 3.5. Trend magnitude (triangle size) and direction (green = increasing trend, brown = decreasing trend) of annual flood magnitude from the 1920s through 2008. Flooding in local areas can be affected by multiple factors, including land-use change, dams, and diversions of water for use. Most significant are increasing trends for floods in Midwest and Northeast, and a decreasing trend in the Southwest. (Figure source: Peterson et al. 2013[63]).

Figure 1: Trends in Flood Magnitude (Weaver, C. P., Mooney, S., Allen, D., Beller-Simms, N., Fish, T., Grambsch, A. E., ... & Langner, L. 2014).

Understanding changing weather patterns includes recognizing the increased frequency and intensity of weather systems in North America (Melillo, J. M., 2014). The insurance industry is warning that private and public property is increasingly susceptible to risk of flooding from both infrastructure failure, pluvial (overland) flooding and fluvial (river overflow) flooding (Warren, F.J. and Lemmen, D.S., 2014). The weather systems that cause these impacts are producing more intense rainfall, faster, and for longer periods of time. Figure 1 shows percentage increases in annual flood magnitude in the U.S.. Note, some areas have growing flood risk while others have much less. In addition to historic impacts, unknown future impacts are changing the susceptibility of North American Real Estate to property damage. This reveals new use and access limitations, which lead to insurability and financing challenges.

The factors that effect flood risk are geological, meteorological, regional infrastructure planning, and local infrastructure capacity. For example: a flood prone region that creates progressive policy and invests effectively in storm water management infrastructure could retain high levels of liveability and insurability, while in contrast a region with low historic flood risk may find emergent weather patterns overwhelm existing infrastructure resulting in flood based water damage. Similarly, homes and businesses that undertake resilience measures on-site may reduce risk to property, and preserve insurability and value, while limiting use-loss and quality of life impacts.

Wind

Two of the most troubling emergent weather patterns are the slowing ground speed of storms and the increase of wind-speeds within storms. The impact to property is increased intensity of property damage. Property damage from wind can be direct and indirect and it can be coupled with other climate risks such as wildfires, storm surges, and ice storms resulting in unprecedented property loss. Wind is increasingly impactful in coastal areas where winds exacerbate storm surge combining with overland flooding to create magnified risk. Wind is becoming increasingly unpredictable contributing to changing direction and ground speed of wildfire.

Tornados and inland storm patterns are changing. “Tornado Alley” in South Central US has shifted eastward exposing new regions to unprecedented wind damage risk. The frequency, magnitude and intensity of tornadoes is resulting in heavier property damage and public infrastructure risk. Unprecedented tornado events are occurring in areas unaccustomed to seeing this type of wind-caused property damage. Increasingly Powerful Tornadoes in the United States (Elsner, J. B., Fricker, T., & Schroder, Z. 2019) evidences the conditions around more frequent and more damaging storm systems. These dynamic wind input variables are exacerbating meteorologists and insurers ability to predict risk, making it more difficult for real estate investors, lenders and insurers to quantify and value real estate impacts from Tornadoes.

There is little that can be done to protect property from wind. While building stronger, more resilient and tighter building envelopes can create some resilience, there are no means to divert, or avoid tornadoes, hurricanes, tropical storms, hail, and wind-affected ice storms. These will have increasingly devastating impacts on communities across the continent today and in the future. Some trends of frequency can define risk-zones, however, never-before events are also increasingly likely to happen.

Drought and Heat

While continental average annual rainfall is increasing, regional changes are bringing increased and decreased precipitation to local areas. For example California's Central Valley, which has benefitted from a perfect growing climate, is suffering drought which is effecting food production and crop yields with billions of dollars of food production at risk. These regional precipitation shifts are resulting in faster spring runoff, lower groundwater stores and longer drought periods across the continent and specifically in Western and Midwestern areas (Cook, B. I., Ault, T. R., & Smerdon, J. E. 2015). The impacts from the changing hydrology relating to climate and drought will affect municipal water use, stress food producers with lower yield and higher crop-irrigation-costs, reduce water availability for rural well-based property, and drought prone municipalities. Drought also increases the susceptibility of crop and natural ecosystems to damage from domestic and invasive pests, which compound land valuation risks, and also increase susceptibility to wildfire.

Property value impact studies on the effects of drought on farmland are speculative, with clear trend toward crop yield and irrigation cost factors (Figure 2). Drought is not as predictable as sea-rise and flood studies, however there is evidence that farmland valuation is directly related to food production and profit. When production is affected the economic yield in both rent potential and necessity for costly irrigation and ultimately profitability are affected. Additionally the impact on resource-based land values such as forestry inventories, and time for resource rejuvenation (the time it takes for a replanted forest to grow) are likely to be negatively impacted by drought.

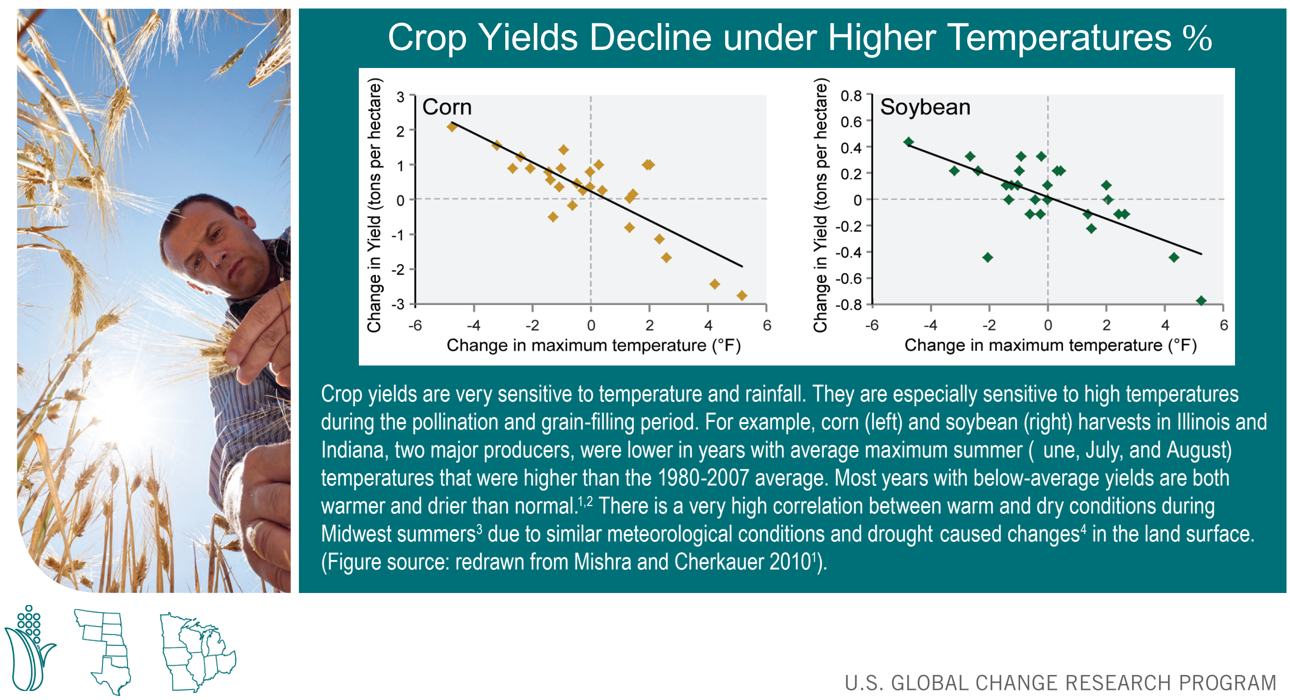


Figure 2: Crop Yields Decline under Higher Temperatures (Weaver, C. P., Mooney, S., Allen, D., Beller-Simms, N., Fish, T., Grambsch, A. E., ... & Langner, L. 2014).

The impacts of drought and heat on property value are clear. Water is central to property value and enjoyment of use. Water is central to agricultural production and food security and will continue to be a major issue for land valuation and is increasing in climate-risk impacts in North America.

Wildfire

Forest Vulnerability to Changing Climate

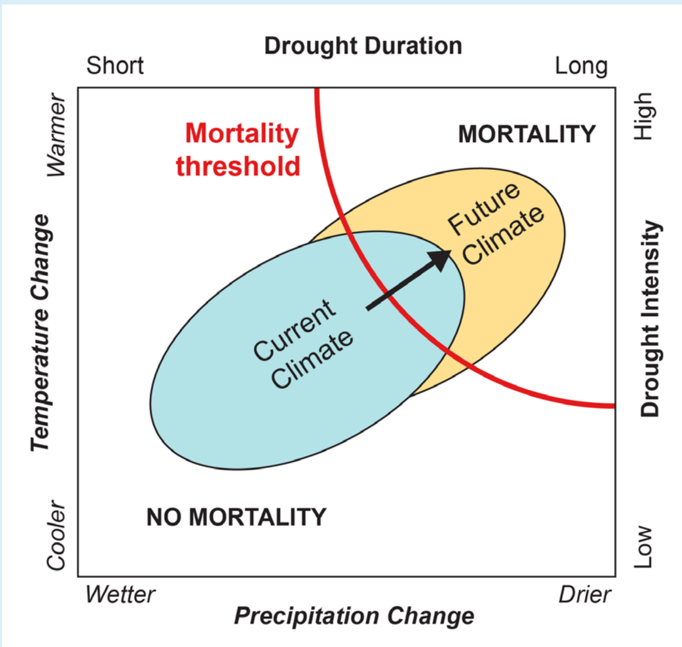


Figure 7.3. The figure shows a conceptual climate envelope analysis of forest vulnerability under current and projected future ranges of variability in climate parameters (temperature and precipitation, or alternatively drought duration and intensity). Climate models project increasing temperatures across the U.S. in coming decades, but a range of increasing or decreasing precipitation depending on region. Episodic droughts (where evaporation far exceeds precipitation) are also expected to increase in duration and/or intensity (see Ch. 2: Our Changing Climate). The overall result will be increased vulnerability of forests to periodic widespread regional mortality events resulting from trees exceeding their physiological stress thresholds.[11] (Figure source: Allen et al. 2010[11]).

Figure 3: Forest Vulnerability to Changing Climate (Weaver, C. P., Mooney, S., Allen, D., Beller-Simms, N., Fish, T., Grambsch, A. E., ... & Langner, L. 2014).

Fire has always presented significant risk to property as shown in Figure 3. Building codes have shifted over time to respond to fire risk, from building envelope based fire separations to fire resistant roofing and exterior cladding materials, fire related insurability has been central to shaping how homes are built, and how landscapes are managed in North America. Firewise USA is a standard for improving infrastructure resilience and behavioural response to wildfire.

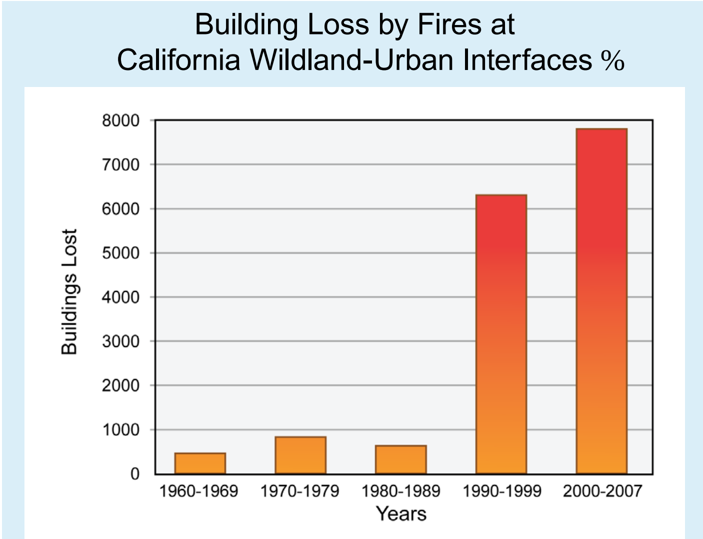


Figure 13.4. Many forested areas in the U.S. have experienced a recent building boom in what is known as the "wildland-urban interface." This figure shows the number of buildings lost from the 25 most destructive wildland-urban interface fires in California history from 1960 to 2007 (Figure source: Stephens et al. 2009[17]).

Construction near forests and wildlands is growing. Here wildfire approaches a housing development.

Figure 4: Building Loss by Fires at the California Wildland-Urban Interface (Weaver, C. P., Mooney, S., Allen, D., Beller-Simms, N., Fish, T., Grambsch, A. E., ... & Langner, L. 2014).

Wildfire has become a prominent risk to property in some regions of the United States and Canada (Westerling, A. L., 2016). The forested parts of Western North America have suffered compounding risk vectors. Invasive species such as pine beetle have left dry standing fuel in forests across the region. Increased dry fuel (dead stand) coupled with unprecedented drought and complicated by dynamic wind conditions have resulted in wildfires that start easily, spread rapidly, change direction unexpectedly, and burn hot and fast (Westerling, A. L., Hidalgo, H. G., Cayan, D. R., & Swetnam, T. W., 2006). Communities that find themselves in the path of wildfire are often surprised, unprepared, and unable to respond except by evacuation. The increased speed with which wildfires are spreading is also making it more difficult for fire suppression and emergency response crews to minimize real property damages and to keep populations safe.

Sea-Level Rise

The oceans of the world are vast, covering 3/4 of the earth's surface. It may be easiest to understand sea level rise by separating the volume of the ocean and its relationship to coastal land. The volume of the ocean is increasing as a result of both the warming of the ocean, which grows the volume of the water (thermal expansion) and from the contribution of water sources, such as the melting of long frozen polar ice caps, and glaciers.

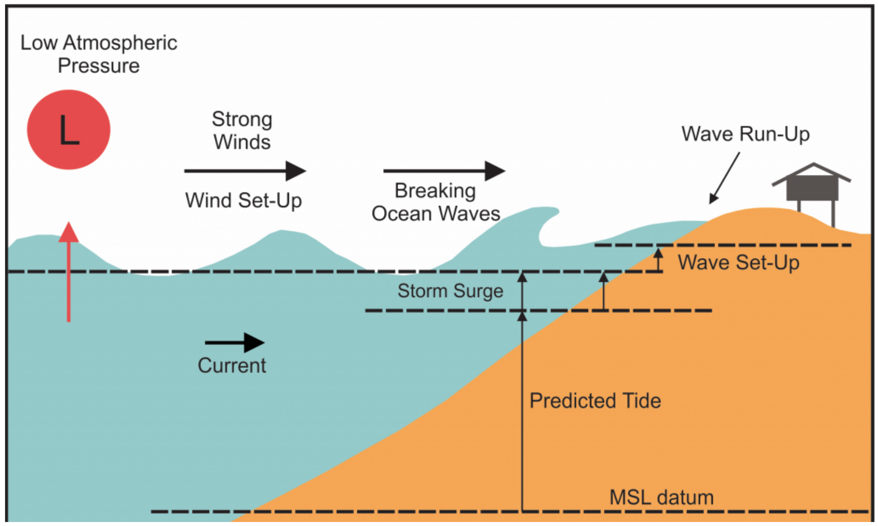


Figure 5 - Understanding Storm Surge (Bush, E. and Lemmen, D.S., editors 2019)

The relation of the ocean to land is also dynamic. If the coast is subsiding (sinking) then the land is going down at one rate, while the sea-level is rising at another rate, the two together mark the measurable location-specific sea-level rise value.

Coastal property globally is susceptible to this phenomena. The sea level rising impacts the land in a variety of ways. Rising oceans can accelerate erosion. Coastal agricultural lands that are near sea level can suffer soil-chemistry impacts that reduce or eliminate crop viability.

Coastal property is most susceptible to risk during weather events which bring intense rainfall, low pressure systems and high winds resulting in storm surge (Figure 5). This magnifies the impact of sea-level rise with heavy landfall storm surge combines with high tides, and potential river, urban and over-land flooding. As sea-level rises, Sea Level is Rising "

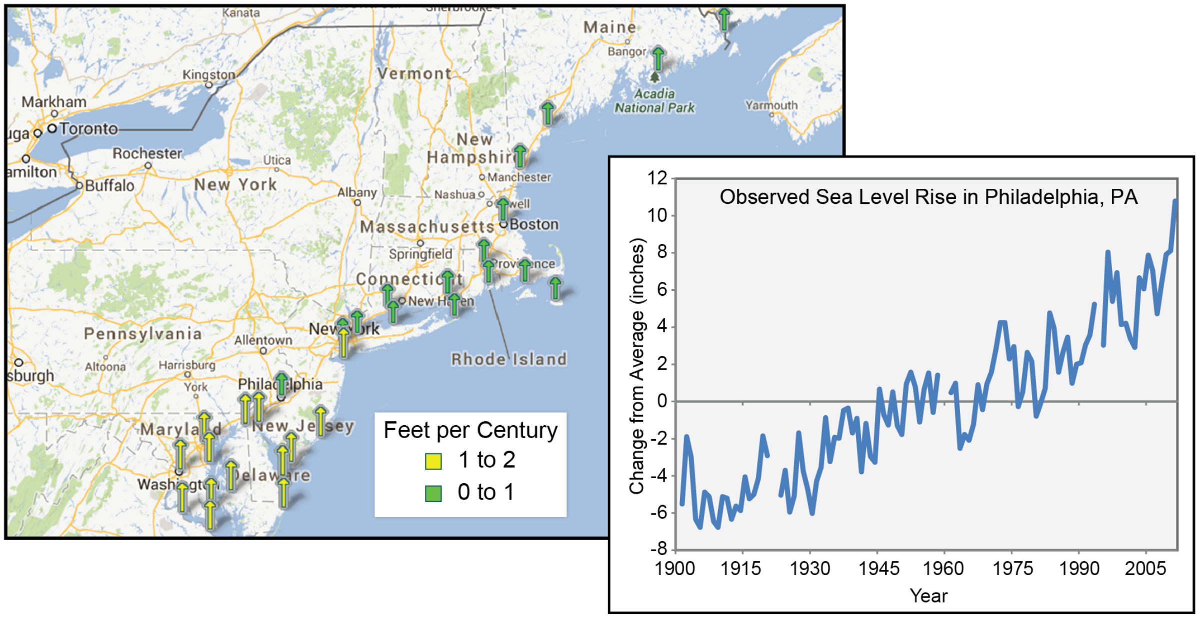


Figure 16.1. (Map) Local sea level trends in the Northeast region. Length of time series for each arrow varies by tide gauge location. (Figure source: NOAA[6]). (Graph) Observed sea level rise in Philadelphia, PA, has significantly exceeded the global average of 8 inches over the past century, increasing the risk of impacts to critical urban infrastructure in low-lying areas. Over 100 years (1901-2012), sea level increased 1.2 feet (Data from Permanent Service for Mean Sea Level).

Figure 6: Sea Level is Rising (Weaver, C. P., Mooney, S., Allen, D., Beller-Simms, N., Fish, T., Grambsch, A. E., ... & Langner, L. 2014).

storm surge effects, including erosion and flooding increase exponentially. As the volume of the surface of the ocean is growing, the impact to potential wave height is exponential not linear.

Additionally, the impact to coastal property is that the landfall of storm surge is likely to increase, meaning properties further from the coast will have increasing risk, and the near-coastal locations will be hit with more powerful and impactful storm surges. Additionally salt water infiltration to fresh water aquifers poses problems for water supply and agriculture. The Northeast United States including Philadelphia PA (Figure 6) have significant risk from sea-level rise, which is compounded when combined with seasonal Atlantic storm surge.

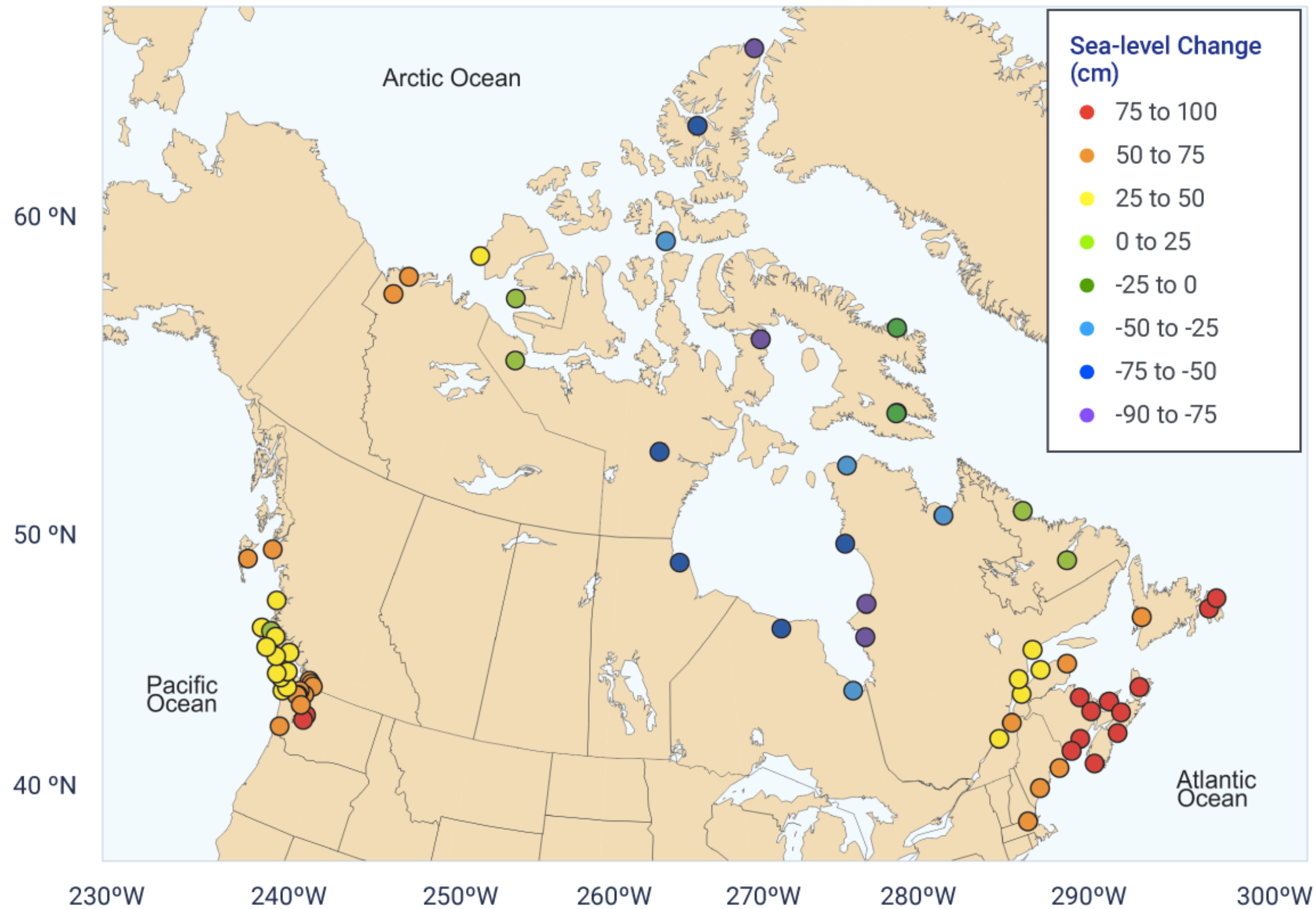


Figure 7: Sea Level Change in Canada (Bush, E. and Lemmen, D.S., editors 2019).

According to Canada's Changing Climate Report 2019 (Bush, E. and Lemmen, D.S., 2019). Coastal flooding is expected to increase in many areas of Canada due to local sea-level rise (Figure 7). Changes in local sea level are a combination of global sea-level rise and local land subsidence or uplift. Local sea level is projected to rise, and increase flooding, along most of the Atlantic and Pacific coasts of Canada and the Beaufort coast in the Arctic, where the land is subsiding or slowly uplifting. The loss of sea ice in the Arctic and Atlantic Canada further increases the risk of damage to coastal infrastructure and ecosystems.

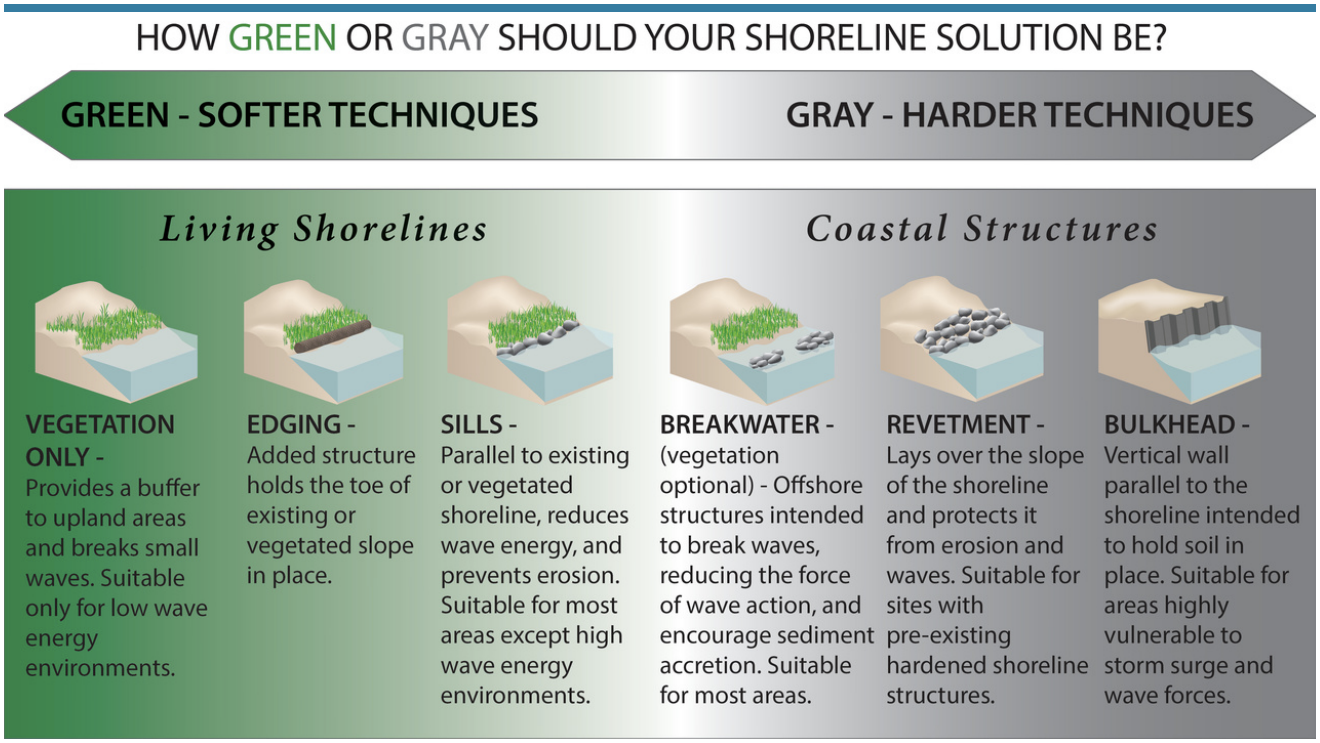


Figure 8: Living Shoreline Strategies Combine with Coastal Erosion Protection (NOAA https://www.habitatblueprint.noaa.gov/living-shorelines/applying-science/tools-for-planning/).

Regional governments and individual property owners can take steps to improve the resilience of coastal property and ecosystems. Hard infrastructure such as retaining walls (Bulkhead) can be integrated with living vegetation to reduce erosion and offer faster ecological recovery from coastal sea-level rise, and increased ocean landfall from storm surge (Figure 8).

THREE HORIZON EXAMINATION OF PAST, PRESENT, FUTURE

The problem of Climate-Risk Value Impacts is a temporal. For many property owners in North America climate-risk is not a question of if, but when. By examining a past, present, future perspective of patterns in scientific data, market psychology, and regional hedonic value studies, clues to emergent real estate value impacts from climate-risk become evident. Hedonic studies involve property value and demand analysis that breaks down research into its constituent property characteristics, and obtains estimates of the contributory value of each characteristic. A simplistic example of this comparison of two houses which are identical, and in the same neighbourhood, one with a garage and one without. The house with a garage is worth more, by examining past sales we can discover the incremental value contribution of a garage as a contribution to value.

Using the three horizon method (Sharpe, B., Hodgson, A., Leicester, G., Lyon, A., & Fazey, I. 2016) the problem of climate-risk is separated into a time and action based rubric: Horizon 1: present day marketplace “business as usual”, Horizon 2: examples of emergent best practices and innovations that are present today combined with points of resistance to change, and Horizon 3: a speculative future snapshot of the marketplace in 2030.

The *first horizon* examines existing market conditions involving an exploration of sociological and psychological values about climate-risk, scientific climate change data, published insurance industry and government market data, and hedonic climate change value-impact studies.

The *second horizon* depicts present day examples of emergent practices of data disclosure, industry knowledge sharing and risk adaptation strategies deployed by property owners, resistance from real estate professionals, tensions for municipalities and public policy makers. Innovations show working examples for approaches to transition-

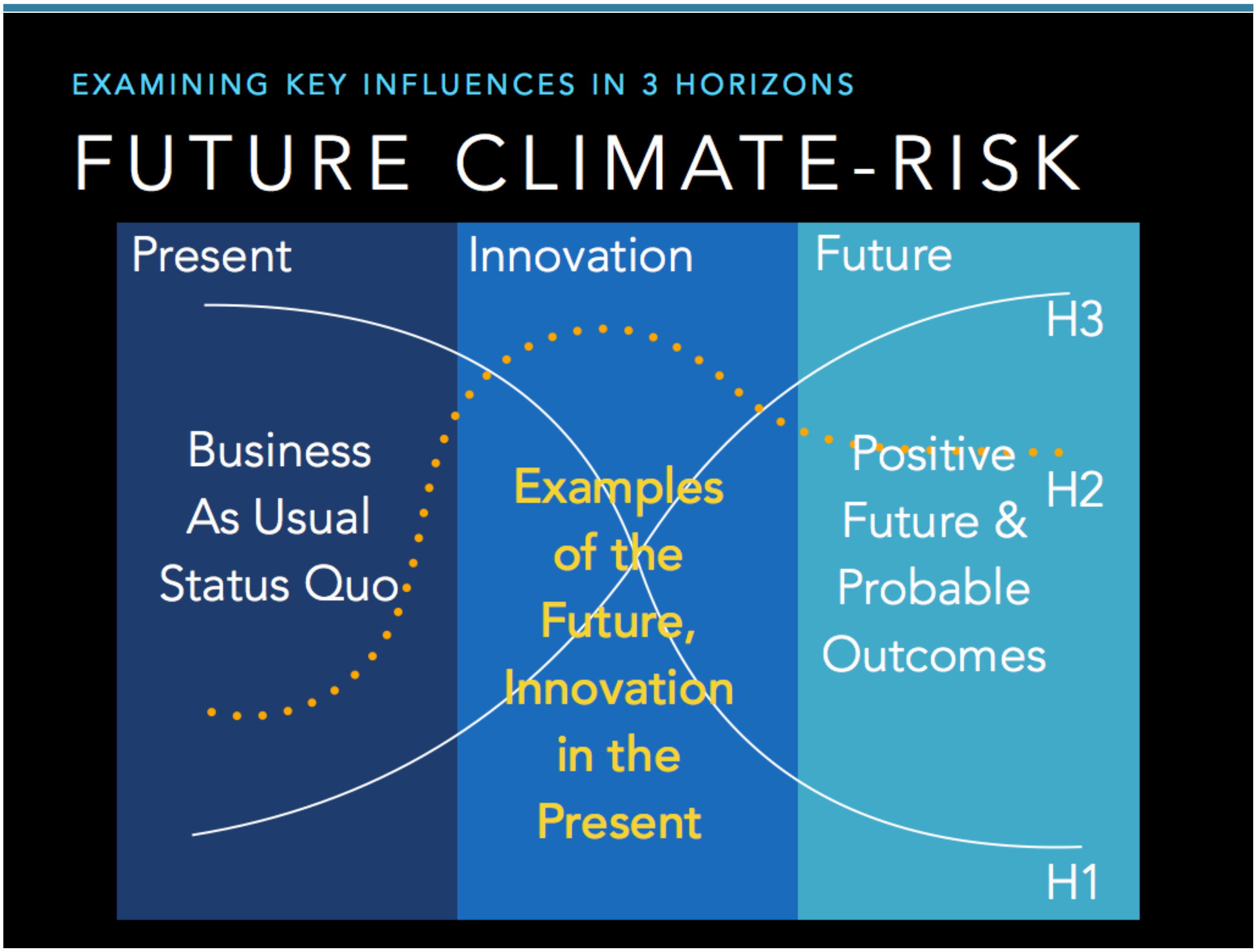


Figure 9: Future Climate-Risk - Three Horizons Method

ing to the emergent market including; consumer and industry acceptance, disclosure, and market valuation of property value climate-risk and integration to everyday real estate transaction.

In contrast examination of a *third horizon* representing a speculative 2030 future provides a canvas for investigation of likely future real estate market conditions related to climate-risk. Here we examine clues that are present in emergent public policy shifts, growing public awareness, and early examples of market response to risk. This offers a picture of the at climate-risk housing market in 2030. This third horizon analysis shapes a positive future, where climate-rick is present in the everyday practice of real estate and consumer behaviour in North America.

First Horizon - Real Property Value Losses, and a Marketplace is in denial

Understanding Market Awareness - and the Attitudes of Property Owners.

Every home owner in North America is at risk from climate impacts. Examining consumer attitudes, and real property value impacts from climate-risk reveals a marketplace in denial. The risk to property owners is greater than the risk to every other stakeholder in the housing supply chain. Every stakeholder has capacity to reduce risk (Figure 10).

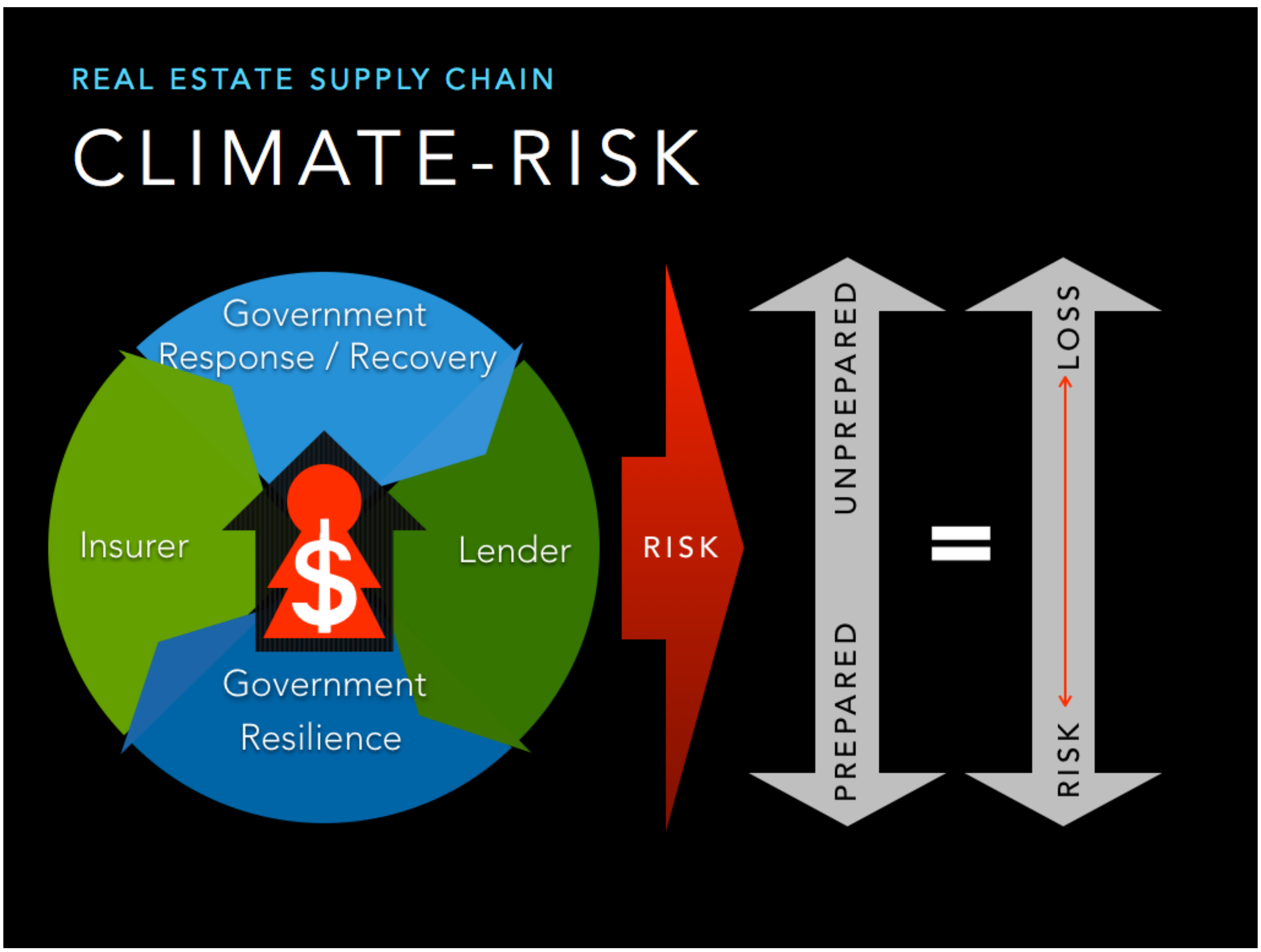


Figure 10: Home Owner at the Centre of Climate Risk in Housing Supply Chain

The entire housing supply chain from property owner to regional government has a role in understanding, measuring and mitigating weather and climate related property risk. Site level property protection combined with regional infrastructure resilience, and regional ability to respond and recover are entwined in valuing climate-risk.

The current market conditions and research indicate that there is a troubling disconnection between actual and perceived property risk. According to a Federal Emergency Management Agency (FEMA) 2010-2013, "Fewer than one in 10 respondents characterized their community as having a "high" risk of flooding". Elected officials were also surveyed in the same study, with "50% agree that there are many available resources, both technical and financial, that can be used to reduce your community's flood risk." Within "FloodMAP communities" "12% of respondents were aware of flood risk to their residences". Canadian statistics for home owner awareness of flood risk report that "Only 6% know they live in a designated flood risk area, and only 21% believe that the risk of flooding will increase over the next 25 years." (Thistlethwaite, J., Henstra, D., Peddle, S., and Scott, D., 2017). This level of awareness of risk is at odds with weather maps which show consistent increases in heavy precipitation in virtually every region in the United States. https://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing#graphic-16693

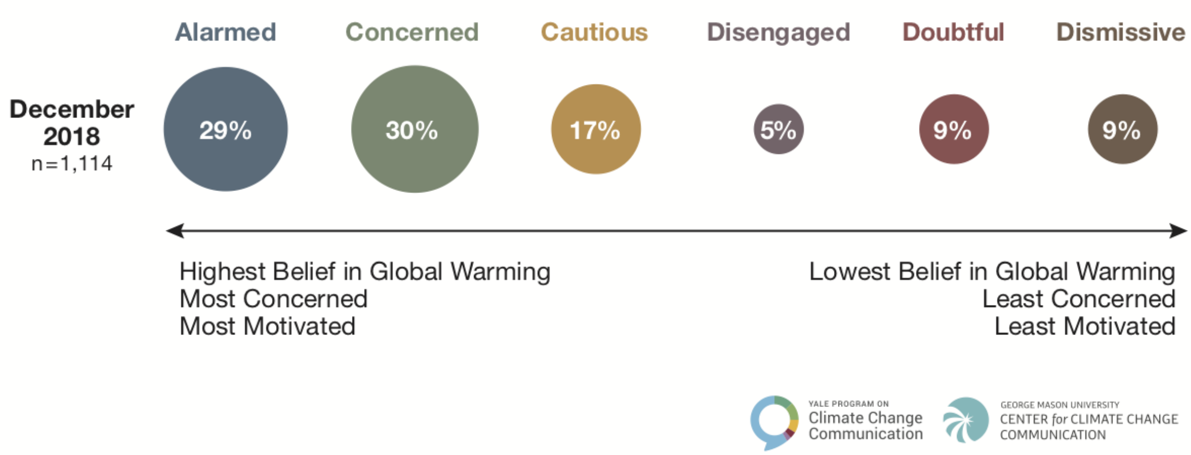


Figure 11: The 6 Americas - Americans Believe in Global Warming (Leiserowitz, A., Maibach, E., Roser-Renouf, C., & Smith, N. 2010)

Social values study ‘The 6 Americas’ indicates that in December 2018 only 23% of Americans are climate change deniers (Figure 11). The Centre for Climate Change Communication and Yale Program on Climate Change Communication survey results demonstrate that there is receptivity within the population to messaging related to climate change (Leiserowitz, A., Maibach, E., Roser-Renouf, C., & Smith, N., 2010).

European study of awareness and action on flood risk has revealed similarly paradoxical contrast between risk, perceived risk and action/engagement (Figure 12) (Wachinger, G., Renn, O., Begg, C., & Kuhlicke, C. (2013). “We found that experience of a natural hazard and trust or lack of trust in authorities and experts are the primary factors that shape individual risk perception of natural hazards in often complex causal arrangements with many intervening factors.”

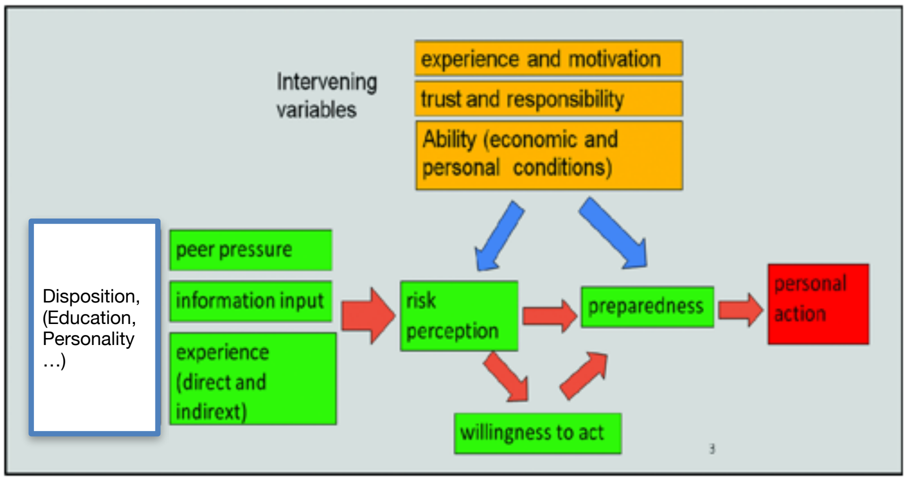


Figure 12: At Risk Populations Awareness and Action on Flood Risk (Wachinger, G., Renn, O., Begg, C., & Kuhlicke, C. 2013)

There remain challenges affecting the willingness to act that are reflected in North America and beyond. If only 6% of Canadians and 12% of Americans believe their home to be at risk of flooding in designated flood hazard areas, how does the marketplace move toward disclosure, valuation and liability for non-disclosure? These disconnections between consumer risk-awareness and market-action provoke questions about both systematic and psychological market barriers to home-owners taking action to protect property. The *paradox of valuation* identifies a systemic aversion to disclosure. Market psychology, and the supply chain of disclosure within the purchase, sale and ownership are complex. Climate-risk valuation, and risk aversion are in tension. The risk is unquestionable, the action and response is inadequate and will be very costly to home owners, governments and the housing supply chain.

The hazard to action-chain (Figure 10) offers an understandable visualization and aggregation of research that reveals a complex system of perception of risk, from broad markets. The findings show that experience, trust of government, and even home ownership can lead to an elevated perception of risk, preparedness and willingness to act (Wachinger, G., Renn, O., Begg, C., & Kuhlicke, C., 2013). This reveals an opportunity to bring at-risk populations together with carefully crafted communications strategies tailored to the local marketplace and the psychographic perspectives of target audiences in order to gain acceptance of the risk associated with changing weather patterns, and their effects on people and property.

Property Valuation Analysis by Category

Studies from around the world offer clues to potential impacts of climate on real estate values. These examples can give confidence in there being an inevitable, measurable and negative impact from climate related risk. The trend of negative property impacts from climate-risk is applicable to jurisdictions affected by climate and changing weather impacts everywhere. These impacts can be direct, as a result of property risk of exposure, proximal, as a result of nearby properties affected, and relational to economic downtime. Risks can include population migration; away from some regions with elevated-risk and repeated-climate-impact-events and toward areas of lower-risk and superior resilience potential.

Investigations into the value impact of California Hazard Disclosure Law (AB 1195) on property values across California, demonstrated average flood plain property sold for 4.3% less than a comparable property not located in a designated floodplain (Troy, A., & Romm, J., 2004). Additionally authors examined literature from Boulder Colorado and Louisiana where there were questions related to the consistency of disclosure, and value of risk of exposure, cost of insurance to ameliorate risk, and timing of disclosure in the sale purchase process. Proximity to most recent flood event, and frequency had a correlative impact on negative price adjustment. AB 1195 requires sellers of properties within statutorily designated natural hazard zones to show prospective buyers a Natural Hazard Disclosure Statement prior to concluding a sale. This relatively low impact as percentage value may be related to disclosure timing, which is subsequent to price negotiation. The small difference could also reflect market conditions of scarcity, competition, economic viability, and risk tolerance, which may not be present in other markets in North America.

Flooding

American regional susceptibility to flooding is increasing in most areas (Figure 13). They vary by location, and have multiple causal sources. Some floods are caused by river-rise, which can be induced by increased rain, snow melt or glacial runoff or a combination of these features. Flooding impacts can be amplified when significant precipitation is accompanied by the failure of a piece of infrastructure, such as a dam, levee, or a dyke. Coastal estuary (river mouth & delta) flooding can bring sea-level rise, and storm surge together with increased upstream water volumes creating amplified impacts and with shorter time to respond. Urban flooding offers a significant potential for property loss as there is a high concentration of valuable land improvements. Reduced permeability in urban areas can result in the urban infrastructure, such as storm sewers, becoming overwhelmed by water resulting in intense flooding, sewer backup, and property damage.

It is generally recognized that an actual flood event, rather than a flood hazard disclosure on a floodplain map, has a greater effect on property values (Yeo, 2003). For instance, in Oregon, several flood events contributed to significant decreases in property value (19% – 26% for flood affected houses), whereas the introduction of a floodplain regulation enforcement did not show effects on residential land value (Mucklestone, 1983). This offers a prospective benefit of disclosure as a tool for reducing climate-risk-value-loss.

Observed U.S. Precipitation Change !

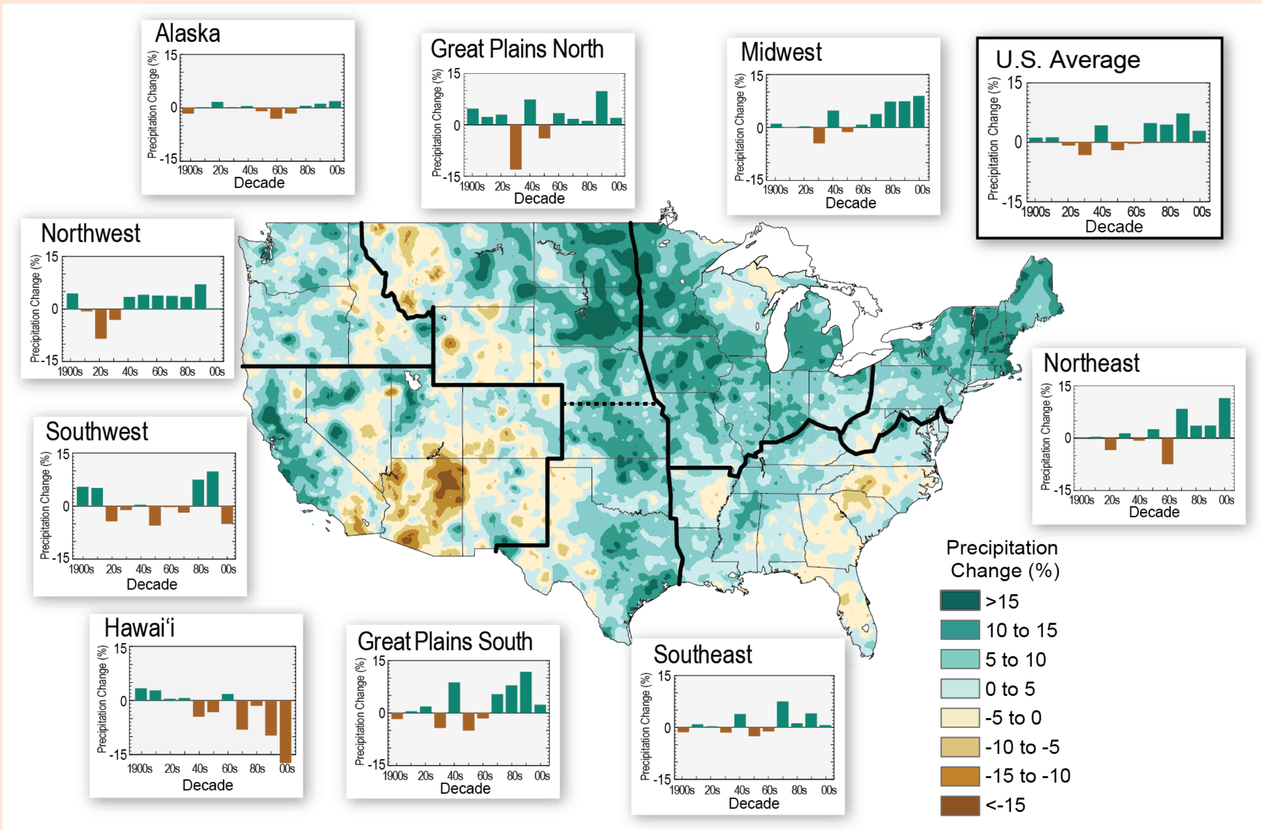


Figure 2.12. The colors on the map show annual total precipitation changes for 1991-2012 compared to the 1901-1960 average, and show wetter conditions in most areas. The bars on the graphs show average precipitation differences by decade for 1901-2012 (relative to the 1901-1960 average) for each region. The far right bar in each graph is for 2001-2012. (Figure source: adapted from Peterson et al. 2013[48]).

Figure 13: Observed US Precipitation Change (Weaver, C. P., Mooney, S., Allen, D., Beller-Simms, N., Fish, T., Grambsch, A. E., ... & Langner, L. 2014).

Actual flood occurrence shows, in almost all cases, negative impacts on the property value. The amount depends on the degree of flooding and ranges from an average of -15% up to -60% for severe property damage. Often, nearby property that is not affected by the flood, also sees decreases in property value. In some cases, the improvements and renovations made after a flood occurrence have increased property value. Recovery time to pre-flood value (or non-significant difference between flooded and non-flooded property) also depended on the severity of flooding event, as well as a number of external factors, and ranged from 6 months to more than 10 years for severe floods, with most studies showing about 3 to 4 years recovery time (Yeo, 2003; Troy, 2003; Eves and

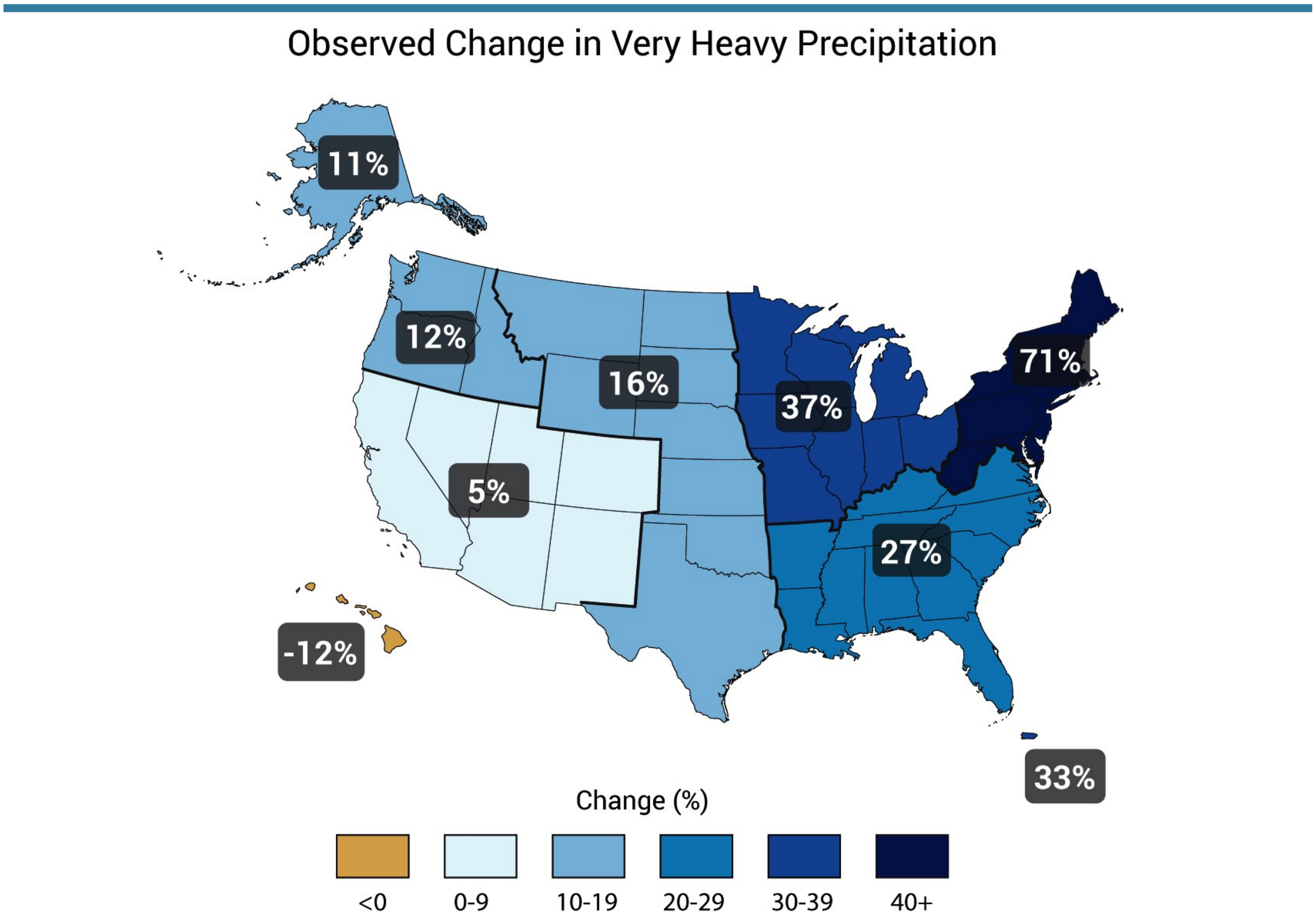


Figure 14: Observed Change in Very Heavy Precipitation (Weaver, C. P., Mooney, S., Allen, D., Beller-Simms, N., Fish, T., Grambsch, A. E., ... & Langner, L. 2014).

Wilkinson, 2014; Tobin & Montz, 1994). Impact on property value increased with re-occurrence of flood (Tobin & Montz, 1994). The market forgets, but the climate-risk does not dissipate with time, it increases.

According to Canada's Changing Climate Report 2019 (CCCP, 2019) in the future, a warmer Canadian climate will intensify some weather extremes. Inland flooding results from multiple factors, more intense rainfalls will increase urban flood risks. It is uncertain how warmer temperatures and smaller snowpacks will combine to affect the frequency and magnitude of snowmelt-related flooding. Similar regional trends are observed in the United States (Figure 14), though many areas are seeing reduced rainfall.

In April 2014, one year after the Bow River flood in 2013 Calgary's housing market was working to recover: Some of the affected houses had price drops from 10% to 25% (Globe and Mail, 2014). The 2014 property assessment saw a reduction in assessed value due to the flood for 1,939 of 450,314 residential properties in Calgary, with an average loss of $208,870 in assessed value for each home damaged (2014). The Calgary example also emerges in our second Horizon (H2) example, in a hopeful response from the local real estate industry and municipality in mitigating future risk, and protecting home value impacts.

Flood mapping can provide detailed insights to flood susceptibility at multiple levels, from building level impacts to neighbourhood or regional. Urban flood mapping can take into account topographical, hydrological and storm infrastructure mapping in order to assess and even test the impact risk of flooding from typical, periodical and extreme events.

Wind

Wind events are often coupled with precipitative events. Property risk is often caused by the wind speeds which damage buildings with direct impacts such as tearing away building materials. In extreme cases tornadoes and hurricanes tear buildings apart. Additionally, damage from wind can be indirect, such as flying debris, and falling trees causing significant personal and property damage. Some areas of continental North America are more susceptible to certain wind conditions from both intensity and frequency of occurrence, such as "Tornado alley" in the Southern United States, while others are subject to hail, hurricane and cyclone events such as the Southeastern and Norhteastern coasts of the United States and Canada.

In an examination of the housing and economy effects for six different areas (Fort Worth-Arlington, Nashville, Oklahoma City, Corpus Christi, Miami, and Wilmington, NC) affected by three tornadoes and seven hurricanes are identified during the sample period. The market responses to severe wind events may be summarized as follows: First, local residential housing prices decreased immediately following a tornado or hurricane. One possible reason for this response is a decrease in the demand for housing. However, this decline in demand is short-lived and is consistent with a temporary stoppage in the in-flow of new residents and/or with the moves of existing residents from one residence to another. The wind disaster disrupts housing activity and prices fall as a result. This study further reflects that there appear to be no market discernment between the kinds of wind events. Hurricanes and Tornadoes have a consistent and similar (negative) affect on the house price index (Ewing, B. T., Kruse, J. B., & Wang, Y., 2007).

Property improvements that integrate provision for human safety have been demonstrated to be valuable in the housing resale market as evidenced in the Oklahoma Saferoom Initiative, which revealed that a shelter increases the sale price of a home by 3.5% to 4% or approximately $4200 given the mean price of homes sold in 2005. The magnitude of the premium is understandable given that shelters retail for $2500–$3000 installed (Simmons, K. M., & Sutter, D. 2007).

Wind is also a complicating characteristic in the acceleration of other kinds of property losses, and risk. Wind is the driving force of storm surge which combines with precipitation to enhance coastal property damage and erosion. Wind is an accelerant, which is increasingly impactful to the ground speed travel and direction change of wildfire. Wind combined with ice storms results in greater infrastructure exposure and property damage from downed trees, power-lines and related property damage .

Drought

Surprisingly drought and heatwaves have historically been responsible for the second most costly insurable risk as indicated in Table 1.

Table 1 Damage, percent damage, frequency and percent frequency by disaster type across the 1980–2011 period for all billion-dollar events (adjusted for inflation to 2011 dollars)

	Number of events	Adjusted damages ($ Billions)	Percent damage	Percent frequency
Tropical cyclones	31	417.9	47.4	23.3
Droughts/heatwaves	16	210.1	23.8	12.0
Severe local storms	43	94.6	10.7	32.3
Non-tropical floods	16	85.1	9.7	12.0
Winter storms	10	29.3	3.3	7.5
Wildfires	11	22.2	2.5	8.3
Freezes	6	20.5	2.3	4.5
Total	133	881.2	100.0	100.0

Table 1: Damage Frequency by Disaster Type, United States (Smith, A. B., & Katz, R. W. 2013)

Floods, wildfires, and droughts are increasing in frequency and intensity and compromise existing infrastructure. In 2017, global losses from weather-related disasters totalled US$320 billion – the costliest year ever. (A Practical Pathway Forward: Removing Barriers to Designing, Financing and Building Climate Resilient Infrastructure | PreventionWeb.Net.)

According to Canada's Changing Climate Report 19, a warmer climate will intensify weather extremes. This will increase the severity of heatwaves, freshwater shortages and contribute to increased drought and wildfire risks. The absence of water and the security of electric power for air conditioning have significant impacts on the benefit and value of use of real estate. The combination of regional food security and land-use planning coupled with cost of living and livability will impact market demand for drought affected property across the continent.

Wildfire

Large increases in wildfire are driven by increased temperatures and earlier spring snowmelts in forests. The greatest absolute increase in large wildfires occurred in Northern Rockies forests. This sub-region harbours a relatively large area of middle and high elevation forest types (such as lodgepole pine and spruce-fir) where fire exclusion has had little impact on natural fire regimes but where an advance in spring runoff produces a relatively large percentage increase in cumulative moisture deficit by midsummer. Most wildfires in the Southern Rockies and Southern California have also occurred in early snowmelt years. The Northern Rockies and Northern California forests are subject to similar conditions. Thus, although land-use history is an important factor for wildfire risks in specific forest types (such as some ponderosa pine and mixed conifer forests), the broad-scale increase in wildfire frequency across the western United States has been driven primarily by sensitivity of fire regimes to recent changes in climate over a relatively large area. (Westerling, A. L., Hidalgo, H. G., Cayan, D. R., & Swetnam, T. W. (2006))

Studies reveal consistent negative property value impacts to real estate both directly and indirectly affected by wildfire. An aggregate hedonic value study in Southern California presents results showing negative and statistically significant property value impacts, evidencing house prices drop approximately 9.7% after one wildfire. Property values suffer a further price drop an additional 22.7% after a second wildfire. (Mueller, J., Loomis, J., & González-Cabán, A. (2009)) Statistically similar home valuation impacts from forest fires were found in Northwest Montana where wildfire has had a dramatic effect on home sale prices, revealing sale prices of homes within 5 km of a wildfire burned area were 13.7% ($33,232) lower than equivalent homes at least 20 km from a fire. Sale prices of homes between 5 km and 10 km from a wildfire burned area were 7.6% ($18,924) lower than equivalent homes at least 20 km from a fire. Sale prices of homes between 10 km and 15 km, and 15 km and 20 km from the nearest wildfire burned area were not statistically significantly different from homes greater than 20 km from a previously burned area. (Stetler, K. M., Venn, T. J., & Calkin, D. E. (2010))

The impact to property value is clear. Myriad studies show that wildfire can have a significant impact on property value (Yeo 2003; Troy 2003; Eves and Wilkinson, 2014; Tobin & Montz, 1994). This can happen within the directly affected areas, in nearby locations and for properties that are in the viewshed of affected property (burned houses or forests can be seen from subject property). Areas impacted by air quality issues, from smoke and impacts to ecological services and wildfire are also prone to value loss. Insurability and finance are connected issues affecting value. Comfort and anxiety affect the desirability of real estate, and the visibility of damage to ecosystems and property can have impacts on property values for years after a wildfire (Garnache, C., & Guilfoos, T., 2018).

Studies evidence that property with site improvements such as non-flammable building materials can have a positive effect on market value despite exposure to risk factors. (Geoffrey H. Donovan, Patricia A. Champ, and David T. Butry, 2007).

Sea-Level Rise

Unlike the other climate change impacts examined sea-level rise is quite verifiable and knowable. The variability in weather could create conditions for unprecedented erosion. Land fall (how deeply inland will a storm surge travel from the coast) and coastal storms will amplify market impacts of ongoing sea-level rise.

Nearly 5 million people in the U.S. live within 4 feet of the local high-tide level (also known as mean higher high water). In the next several decades, storm surges and high tides could combine with sea level rise and land subsidence to further increase flooding in many regions (Melillo, J. M. 2014).

The Canadian government is less specific in defining the impact on the Canadian population, however they do reference Intergovernmental Panel on Climate Change (IPCC) and other international findings that specifically state the potential for increased risk to coastal erosion for Pacific, Atlantic and Arctic regions due to sea level rise, storm surge, and the probability for severity of storm systems is increasing. Regions that are projected to experience an increase in mean sea-level are also likely to experience increasing extreme high water levels.

Canada is surrounded by oceans. Populations and land use on all seafronts will be affected, with unknowable risk to landmass in permafrost locations where subsidence from permafrost-thaw could accelerate coast erosion.

In a compelling analysis of coastal property value impacts from sea-level rise in North Carolina that integrates geospatial (topographic and geographic information systems (GIS)) with hedonic property valuation revealed a complex and understandable perspective of property-value-risk. The study specifically identifies that coastal property with lower elevation provide closer access to shoreline delivers a positive impact on value, yet property with lower elevation also has greater susceptibility to sea-level rise and storm surge. This study looks at property impacts in future sea-rise scenarios and offers some significant insights. Through GIS imaging the study is able to identify properties at risk along a timeline, and to estimate the value impact to local housing marketplaces as a percentage loss. Without discounting, the residential property value loss in Dare County, North Carolina ranges from $136 million (1.24 percent of the total assessed value) to $1040 million (9.45 percent of the total assessed value). While there is significant complexity in studying and estimating these impacts there is a clear indication that proximity to ocean front creates significant price premium, and that lower elevation create significant and predictable future devaluation. At individual property devaluation applies specifically to sea-level rise scenarios, which put the number of residential properties at the risk of inundation ranges between 487 (2030-Low) and 3737 (2080-High) (Bin, O., Poulter, B., Dumas, C. F., & Whitehead, J. C., 2011). While the statistical numbers appear to be insignificant en masse, as a market statistic, $136 million in losses across 487 properties indicate average (minimum Sea-Rise impacts to) individual property losses of $279,260.78. The study also identifies that insurance is limited to losses of $250,000.00 and that pertains only to the value of site improvements and not to devaluation of the land-asset.

Residential areas with knowable sea-level rise are part of every coastal housing economy in North America. Additional studies have been done to evaluate the impact on coastal lifestyle benefits including beaches. “Our simulation results indicate that the value of coastal residential (and vacation) property can fall by as much as 53% in places like Carolina Beach when the baseline erosion triples and variable costs of sand quadruple.” (Gopalakrishnan, S., Smith, M. D., Slott, J. M., & Murray, A. B., 2011). This becomes an important perspective relating to coastal property valuation, municipal investment in property amenities, and preservation of value over time.

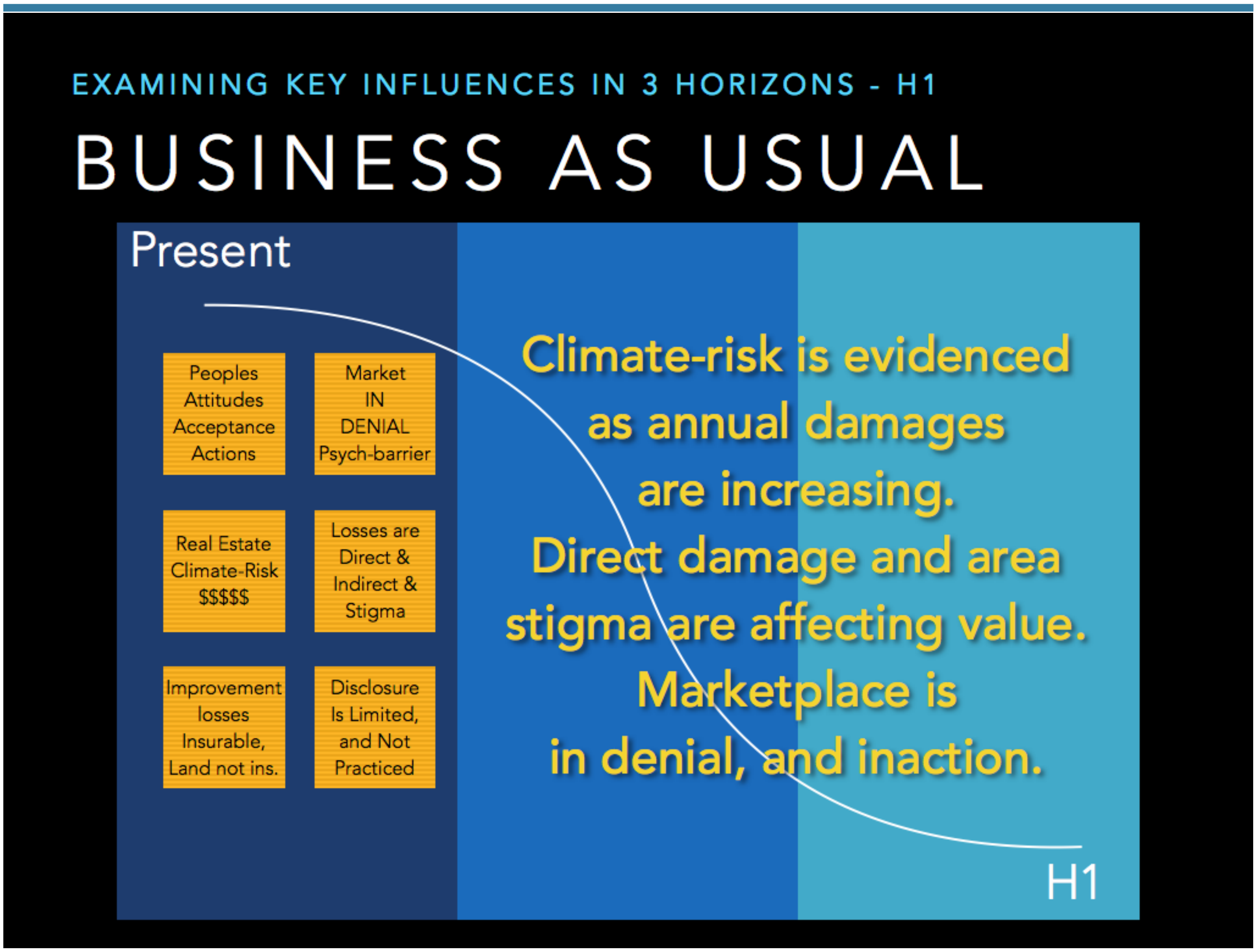


Figure 15: Business As Usual First Horizon Summary

Horizon 1 Summary (Figure 15)**:**

Examination of past and present market of climate impacts on property valuation shows some troubling characteristics of the status quo. The denial of risk by the public, and the complexity of their interaction with government and hazard risk are troubling (Wachinger, G., Renn, O., Begg, C., & Kuhlicke, C. 2013). Insurance industry and government research data evidences a surprising lack of perceived risk from at risk property owners. The question informed from this data analysis is; 'Is the North American home owning public in denial about their risk of property loss from climate change?'

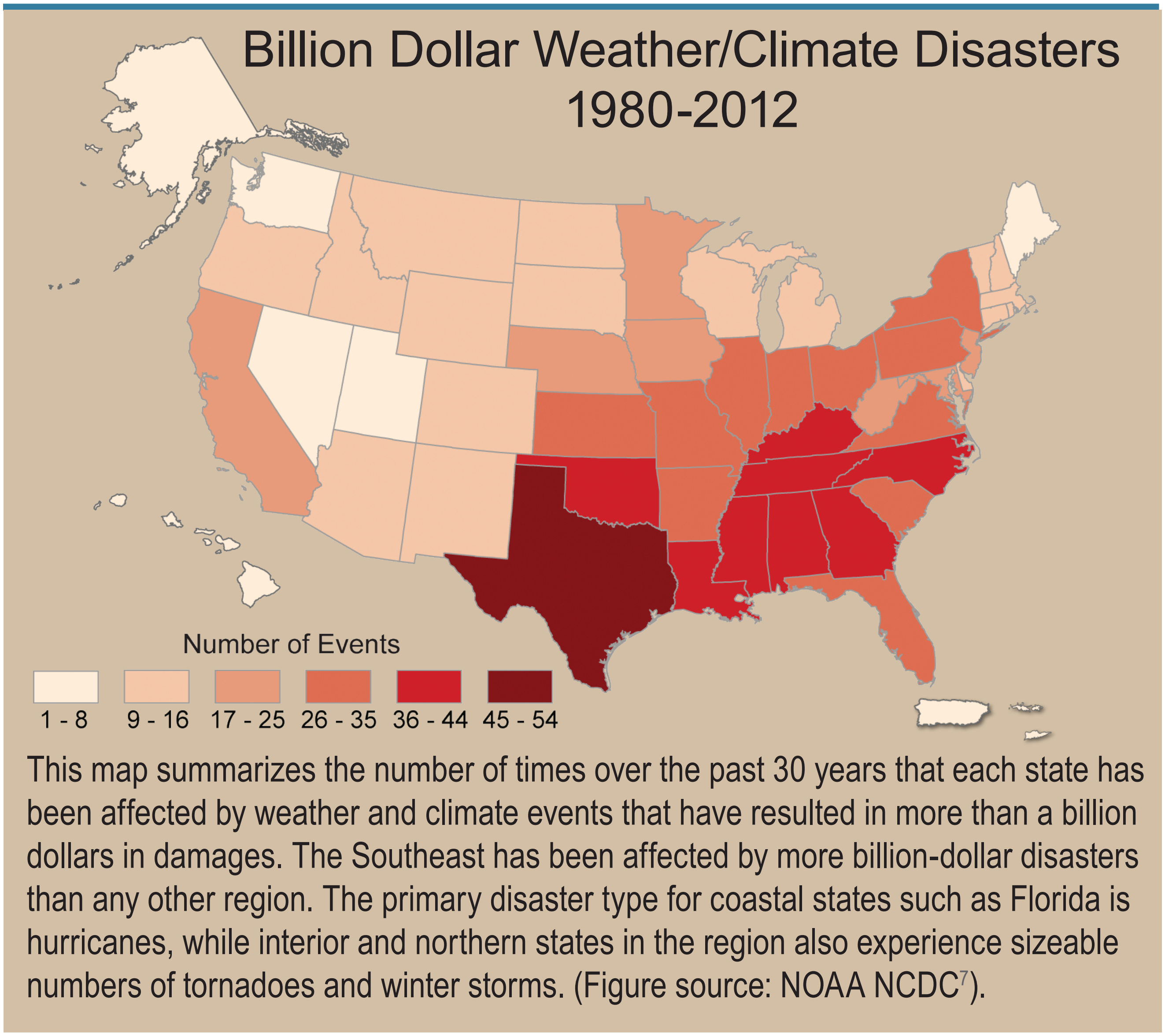


Figure 16: Billion Dollar Disasters (Weaver, C. P., Mooney, S., Allen, D., Beller-Simms, N., Fish, T., Grambsch, A. E., ... & Langner, L. 2014).

Homeowners in North America are being impacted by catastrophic events (Figure 16). These impacts take the form of both insurable risk and uninsured losses. Property value loss suffered from reduced demand for property affected by climate events suffer land value losses which are not insured. Insurable losses may account for much of the site improvement replacement costs, however, typically much of the value of real estate is in the locational benefits of the land. The insured and replaceable site improvements can be rebuilt. Degraded value of use, and stigma after a catastrophic event do not recover quickly and may never recover. These losses affect individuals quality of life and wealth. Negative property value impacts occur to property damaged by severe weather, flood, drought, wind, wildfire, and sea-level rise. Adjacent and in view-shed properties are also affected. Area properties that are valued in proximity to eroded amenities such as beach front, or forested national parks, can also suffer negative market value impacts. The supply chain supporting homeownership in the US and Canada appears to currently be ineffective at conveying the value associated with climate-risk impacts. This phenomena is not isolated to Canada or the United States. It seems to be an endemic problem of global proportions. These issues raise a number of important questions for the real estate industry. Can the housing supply chain shift in order to enable preservation value through resilience investment? Does the housing market hold risk for non-disclosure? If a property is sold, and is known to be at risk of climate hazard, does the seller hold liability, does the Realtor®, does the municipality?

Climate change will impact more homeowners across the continent in coming years. Some of the impacts such as sea-level rise are quite easy to anticipate due to the availability of data and the knowability of the shoreline impact. Other impacts will be very tough to anticipate, as shifting climate patterns are very dynamic, with only trend based data to indicate emergent risk. Scientific data trends are knowable. Infrastructure resilience is knowable. Existing flood and wildfire risks are knowable. Regional historic and changing weather patterns are knowable. This knowable information should be made accessible to the public in an understandable way that allows for the definition and disclosure of climate-risk. This is currently rarely the case.

A pattern emerges in the first horizon revealing the complexity of human psychology that must be reconciled in order for property owning (and renting) populations to comprehend and act upon climate-risk. Climate-risk is real, in the present day. The impacts to home owners are severe to personal property based wealth, quality of life, and personal psychology..

Second Horizon - Innovations Today. Examples for Market Response.

Human Impacts Are Real

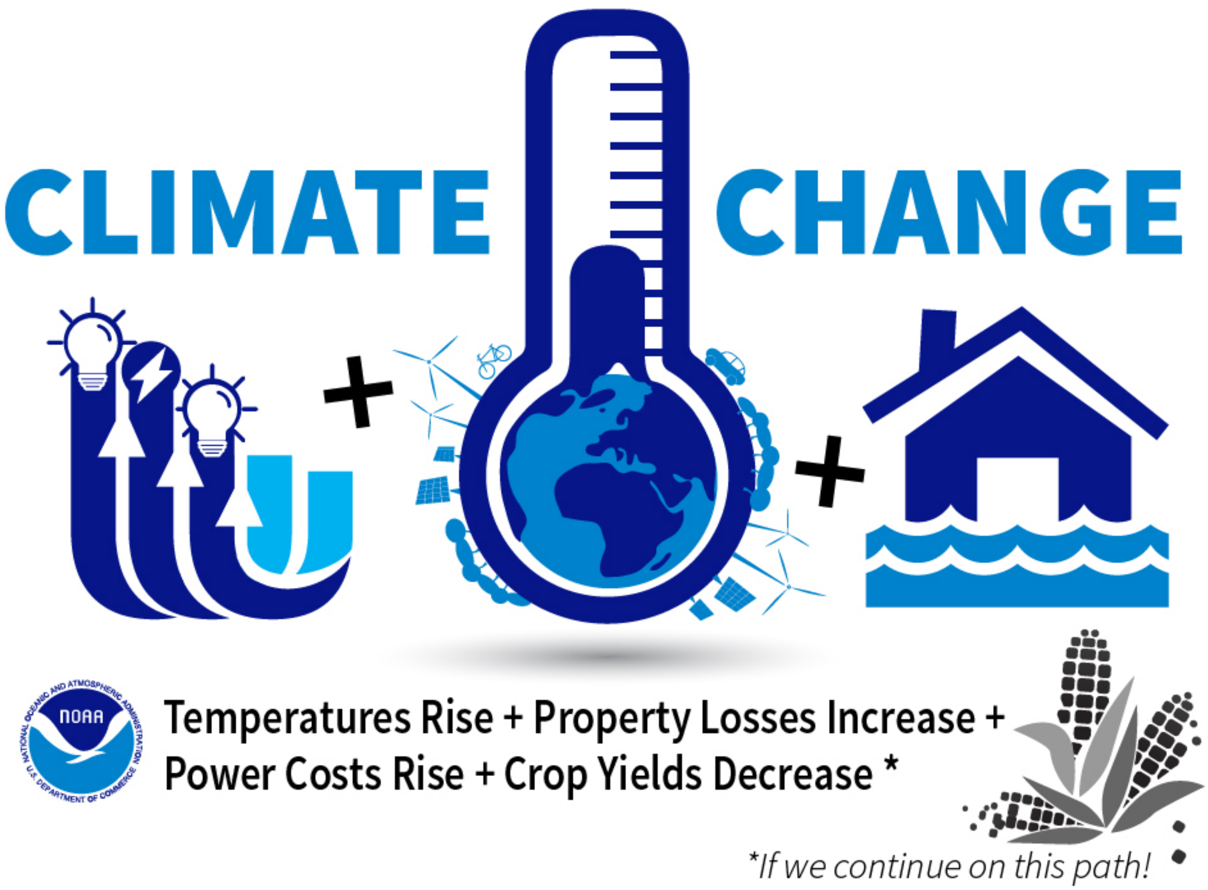


Figure 17: Losses Expected to Increase $7.3 Billion More Per Year in the United States (https://www.coast.noaa.gov/states/fast-facts/climate-change.html).

Personal stories from homeowners who have suffered through property losses from catastrophic weather events are abundant. The statistics of extreme weather event impacts on people are aggregate evidence of personal stories of property loss (Figure 17). Family homes have been destroyed, lives displaced, sometimes forever, and sometimes with lasting devastating impacts to personal identity, wealth and quality of life. The psychological and physical suffering of individuals is understandable, and vivid. Post-Katrina examination of residents returning where interview data considered suggest that the evacuation experience created a context in which 'Ninth Ward residents' sense of place was raised up. The level of consciousness and that the disruption in their place attachment made return desirable since their sense of contentment, well-being, and even self could only be found in New Orleans.'. While many former residents chose not to return, "the arguments we make about sense of place are situated within one particular context in one particular historical moment, we believe that the analysis presented here points the way toward a larger discussion about the role sense of place can play in guiding action at an individual level and in overcoming complex social coordination problems, particularly those presented by a post-disaster context." (Chamlee-Wright, E., & Storr, V. H. 2009). This post event perspective gains value in when coupled with pre-event market risk and action analysis to provoke a Service Design Research question: How can property owners be effectively engaged in understanding climate-risk and acting upon it in order to preserve wealth and quality of life?

Risks are Knowable and Predictable

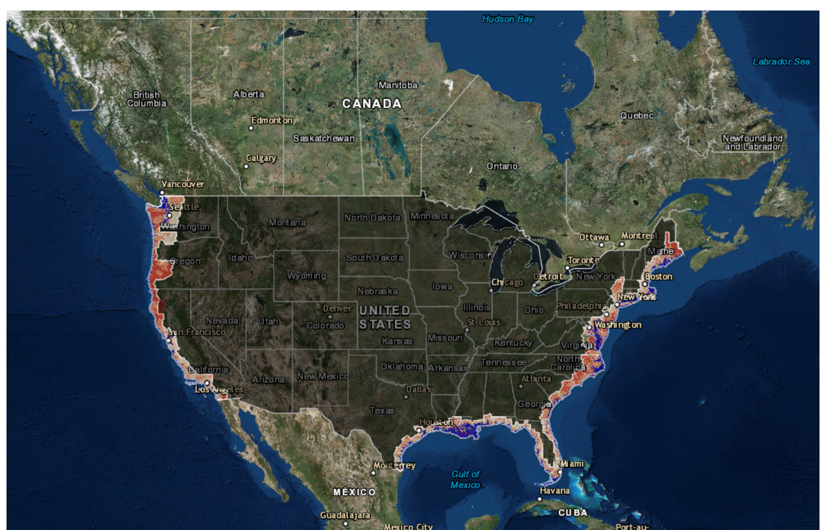


Figure 18: Coastal Vulnerability in the US https://coast.noaa.gov/slr/#/layer/slr

The National Oceanic and Atmospheric Administration (NOAA) has published coastal sea rise mapping tools that are accessible to everyone with a decent computer and internet connectivity. This tool allows individuals to zoom in and out of coastal locations and to choose the intensity of sea rise, the timeline between now and 2100 (https://coast.noaa.gov/slr/#/layer/vul-soc/0/-11581024.663779823/5095888.569004184/5/satellite/none/0.8/2050/interHigh/midAccretion) This tool allows

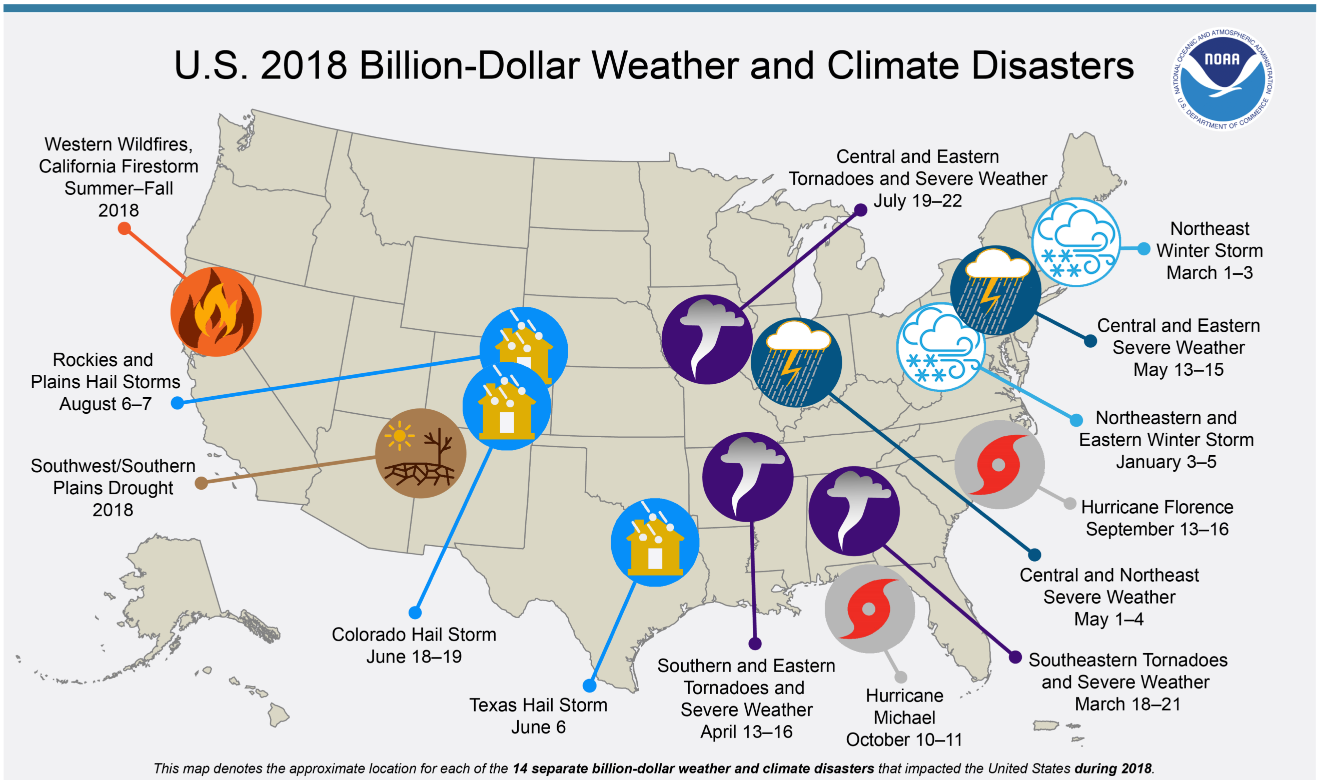


Figure 19: Billion Dollar Disasters NOAA National Centres for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2019). https://www.ncdc.noaa.gov/billions/

for a view of the inevitable impacts on coastal property from seal-level rise. This tool can specifically locate expected sea rise impacts to specific areas, at a future point in time, based on the speed and intensity of sea rise projections. From a real estate investment perspective this allows for the simple and subjectively flexible method of understanding future investment risk, today. For example this tool could allow for the prediction of the location of future waterfront property, or for future prediction of property that is likely to be inundated by sea level rise. With this in mind, we can see an evidence based perspective of future risk for Sea Level rise in the United States. This Map which was generated by the NOAA online Sea-Rise tool offers insight to the extent of the at risk coastal landmass in the United States (Figure 18) which is vulnerable to coastal flooding.

Similarly we can look at scientific data regarding wind, wildfire, flooding, and drought and trend impacts on use and value of real property. Understanding regional weather-based hedonic study of past property value impacts demonstrates negative property valuation from climate change related incidents. While prediction can not be as clear about the specific foreseeable impacts from climate risk from Wind, Wildfire, Flood and Drought as we see with Sea-Level Rise, the trends clearly demonstrate emergent risks are predicted, their impact is statistically measured and the cost of these increasing impacts (figure 19) will be born by property owners, their lenders, their insurers and by governments . These are not unknowable risks, they are predictable to some extent. When we couple these understandings of past property value impacts from climate change with the scientific forecasts of increased frequency and intensity of severe weather, evidenced by the global scientific community including the International Panel on Climate Change (IPCC) and national and regional governments in the United States and Canada, we find that there is a clear emergent risk to the supply chain of home ownership across North America (IPCC, 2018NOAA map (Figure18)). This simple understandable perspective of regional property damage in the United States in 2018. demonstrates that regional climate change impacts are clear.

Analysis of local flood mapping, infrastructure vulnerability and meteorological data can provide significant insight into the type and probability of property devaluation as a result of climate change events. According the the Canadian government 'Climate change, via an increasing incidence of severe weather, has become an important risk management issue for Canada's insurance industry. Insured losses for weather-related claims have been near or above $1 billion in each of the last six years (2009-2014). In 2013, flood damage in southern Alberta and Toronto and an ice storm in Southern Ontario and parts of Eastern Canada pushed insured losses to a record $3.2 billion. Insurance claims resulting from water and wind damage caused by severe weather make up more than half of all property insurance claims, and are now responsible for more claims than damages caused by fire.' (Environment and Climate Change Canada, Nov 2015).

At a conference on flood mapping in Toronto, Natural Resources Canada researchers presented geospatial flood mapping tools that will be made available in whole or part to Canadians (Lindsay, Tina, & Heather McGrath, 2019) which disclosed that Canada is creating a National flood mapping tool, which will allow for neighbourhood level flood risk assessment with unknown level of market coverage.

2019 reveals harbingers of improved data access emerging which will allow for individual property owners, and real estate investors to assess climate-risk. Robust meteorological data sharing and scientifically examined predictive risk assessment tools (2-12 years) data that will allow homeowners, Realtors(r), lenders, insurers, and governments to assess climate-risk and make it central to the marketing and sale of property. Governments, industry and individuals who choose to perpetuate active denial of climate-risk do so with knowable liability risk and predictable loss of wealth.

Fulsome Hazard Disclosure Demonstrates Emergent Market Best Practices

Public policy, consumer demand and industry disclosure are emerging in regions already impacted by climate-risk. In California hazard disclosure within the context of real estate transaction is law requiring disclosure of any or all of the following prior to sale of property:

- A special flood hazard area designated by the Federal Emergency Management Agency.
- An area of potential flooding in the event of a dam failure, designated by the state Office of Emergency Services.
- A very high fire hazard severity zone designated by the California Department of Forestry and Fire Protection.
- A wildland fire area that may contain substantial forest fire risks and hazards, designated by the State Board of Forestry.
- An earthquake fault zone designated by the State Geologist.
- A seismic hazard zone designated by the State Geologist.

The California example illustrates that policy framework that effectively integrates into property sales process. This is positive, however the timing within the sales process offers non-ideal disclosure timing.

In Calgary, AB, Canada., following the Bow River flood where approximately 20% of Calgary's housing market was affected by Fluvial to flood risk (river rise), the local real estate board and the municipality collaborated in creating a listing and selling resource that provides flood-mapping-integrating locational benefits such as walkability and transit score with flood-mapping within the real estate sales process at time of showing and purchase (Chopik, Feb 12, 2018).

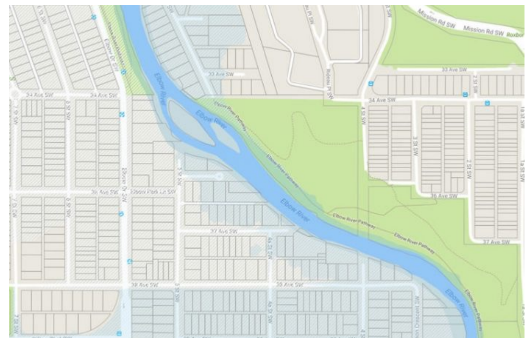


Figure 20: Calgary Real Estate Board Flood Mapping Tool (https://www.remonline.com/flood-real-concern-property-valuation/)

In Edmonton, AB, Canada, a Freedom of Information and Privacy request by Postmedia resulted in the of City of Edmonton flood maps (City of Edmonton, 2016). The City has released flood mapping data, allowing the housing supply chain including purchasers, sellers, Realtors(r), lenders, insurers and service providers to understand Pluvial (overland flooding), fluvial (river flooding) and sewer overflow flood risk. This level of public engagement about property flood risk has resulted in a shift in political and public awareness in Edmonton. In March 2018, Edmonton Mayor Iversen lead thousands of global members to sign the Edmonton Declaration committing to 'various actions including a call on the scientific community and other levels of government to provide better data and tools for science-based decision-making.' (City of Edmonton, 2018) This leadership demonstrates the potential for participation for all stakeholders whereby government policy makers and the public come together to understand latent risk and to find better ways to protect from future risk.

North Carolina is one of the few regions of North America where comprehensive flood mapping is accessible to the public (North Carolina Department of Public Safety, n.d.). Anyone can pull up the website and plug in a ZIP code or street address and discover the property/neighbourhood risk level. This kind of disclosure of risk allows property owners and investors to understand and respond to risk related to their property and investments. This example allows for all suppliers within the real estate transaction to avoid liability related to non-disclosure, and unknown future impacts.

In Quebec, Canada, following extensive spring flooding (April 22, 2019) , Premier François Legault announces limitation to flood victim compensation, and incentive for relocation out of at risk flood locations. This legislation will limit the compensation for property reparation to $100,000 CDN and incentivize relocation. This offers a leading approach to government response to catastrophic flooding, while protecting tax payers and residents (CBC April 22,2019).

Montana introduces FireWise a resilience program that includes; fuel treatment, resilient buildings responsive residents borrowing from Australian system for wildfire management strategies actively engage occupants of the Wildland Urban Interface (WUI) communities near wildfire hazards) in actions that can reduce losses of life and property. Annual fuel treatments including limiting vegetation (fuel) near to buildings will not eliminate fire-risk; they will effectively modify fire-response behaviour. Study of fire behaviour demonstrates that Ii landscaping and structures are not designed and built specifically to resist (wildfire) ember attack, the structures will be vulnerable to fire loss. "However, if residents accept the fact of inevitable wildfires in the interface and accept the fact of their responsibility to prepare a fire resistant home and landscaping well in advance of subsequent fire seasons, then they will find themselves in the enviable position of having interface choices: either *going really early* ahead of wildfire threats or *staying and defending* their home against the inevitable ember attack." Two districts, one in Montana and one in California, demonstrate meaningful benefits in having options for interface survival—survival that includes the resident as an essential participant. (Mutch, R. W., Rogers, M. J., Stephens, S. L., & Gill, A. M. 2011). The most promising aspect of this innovation is that it involves policy, precaution and participation from the property owning public and firefighters in reducing the effects of wildfire disaster on property. This same approach is lauded for other disaster types where shared and cumulative risk benefits can be accumulated through planning, retrofit and incident planning.

The Institute for Catastrophic Loss Reduction (ICLR https://www.iclr.org/) is an insurance industry funded world-class centre for multidisciplinary disaster prevention research and communication. Their outputs advocate for greater resilience and a "build back better" protocol for disaster recovery. The Institute generates research and communication tools that can assist home owners, insurers and municipalities in creating resilience. Their prescriptive guides for home owners allow for a clear project path from sight design to building design and retrofit for multiple risk types. Similarly they offer well researched approaches for municipalities to plan for and recover from catastrophic loss as a result of extreme weather events including Wildfire, and Flood. They advocate "build back better" approaches for infrastructure renewal in order to reduce future property damage and risk.

Researching the relocation of populations in Miami, FL, Harvard researchers have coined a new real estate term, Climate Gentrification. They suggest that affluent real estate investors are displacing populations with historically lower property values as they migrate away from at risk coastal locations. This move to higher land elevation, in Miami, FL to higher elevation in response to climate change risk. The authors define this migration to lower risk locations as Climate Gentrification.

Authors challenge land urge regulators to evaluate the relocation and densification patterns in order to build a sensitivity to the economic effects of climate change, and adaptation on property markets within existing policy regimes. The goal is that climate migration does not displace, but includes, populations that are being pushed out by Climate Gentrification. The motive that is driving Climate Gentrification demonstrates a real estate investor interest in and awareness of the impacts of climate change on real estate values. While researchers are relocating to avoid cost burdens such as investment in resiliency measures, higher insurance cost or nuisance avoidance a theory of Climate Gentrification gives recognition to the various pathways by which climate change impacts may drive investment and settlement patterns. In Miami, Climate Gentrification has been speculated in popular discourse to already explain gentrification patterns. (Keenan, J. M., Hill, T., & Gumber, A., 2018).

The Urban Land Institute says that climate change has shifted the landscape of risk for communities around the world. Annual risk exposures can be calculated for future years and aggregated to understand the net present value of the total risk the community faces. Municipalities are in a position to assess the risk that their communities are exposed to (Urban Land Institute, 2015).

Horizon 2 Summary

Beyond the dollars and cents of property value loss, the loss of life, identity and the human suffering that accompanies loss are real impacts from climate on property. The displacement of people, and the erosion of their financial and emotional capacity to respond will be important considerations for disaster relief programs. Post climate catastrophe responses are ideal research grounds for developing better service delivery and helping to reduce property losses. Anticipating disaster recovery will be an increasing reality, service research design should be integrated in disaster response protocol in order to adaptively respond with increased efficacy to increasing human and system impacts from climate change.

The knowable and predictable climate impacts that are available in aggregate are accessible to the housing supply chain need to be made understandable to citizens. Sea-level rise is clearly knowable, and so are changing meteo-

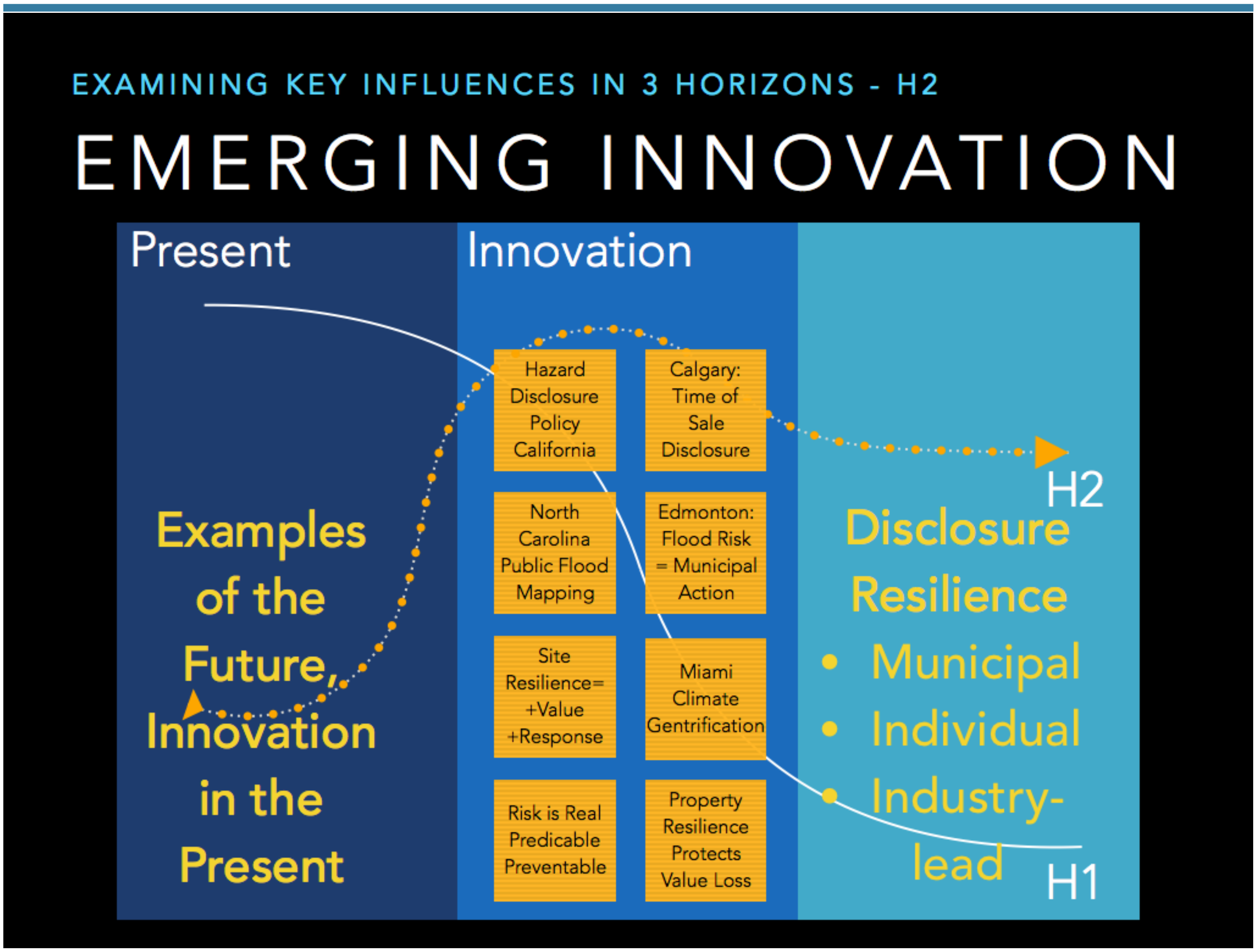


Figure 21: Horizon 2 Emerging Innovations. Examples of the Future in the Present

rologic trends. The fluvial and pluvial flood risk is typically knowable, municipally, and regionally. Wildfire trends are knowable, and predictable. Drought and desertification are predictable trends in changing climate. The trending increase in wind related property impacts are knowable. These knowable impacts are very complex and outside of the life experience and knowledge base of the average North American citizen. Property owners across the continent can benefit from understanding these complexities and their direct impact to personal property ownership. Governments, insurers, Realtors(r) and lenders have an important opportunity to communicate risks to homeowners despite the fact that it is at odds with short term financial interests.

Fulsome hazard disclosure demonstrated in California's Hazard Disclosure law, while imperfectly timed in the sales process, shows promise for how policy can assist the market to integrate risk into the buying and selling process. North Carolina flood mapping disclosure is a strong example of how flood risk can be communicated in a usable and accessible way that can create market-wide awareness of risk, and time of sale information that allows the market to understand and value potential risk. The City of Calgary and the Calgary Real Estate Board have set a standard for the integration of flood risk within the real estate purchase and sale process. This approach offers an example of emergent best practice in disclosure. Disclosure de-risks the seller and Realtor® from misrepresentation and offers a pricing of risk at the time of purchase. Edmonton's disclosure of infrastructure susceptibility to urban flooding has created a political climate where constituents support investment in infrastructure resilience. Site-level home owner investment in resilience promises to be more valuable and desirable when the market is aware of risk.

Montana's implementation of the Firewise program provides a unique blend of property improvement for resilience and human behaviour based risk reduction (Mutch, R. W., Rogers, M. J., Stephens, S. L., & Gill, A. M., 2011). This integration of both the site level risk reduction and the homeowner response shows an adaptive strategy that creates a societal adaptation capacity cogent to asset resilience. This integration of the human factor creates the capacity for systemic social innovation, collaboration with others and for the spread of ideas. The Institute for Catastrophic Loss Reduction (ICLR) 'solutions for home owners and municipalities' offers a trans-climate-impact, and trans-stakeholder approach that has the potential to provide a framework to bring benefits seen in Montana Firewise roll out to regions across the continent suffering from diverse risk types.

Climate Gentrification offers clues for profiteers looking for future real estate market opportunities from climate change impacts on North American real estate values. Quebec's recent flood relocation policies create motive to relocate to safety. Domestic climate migrants will include Climate Gentrification. The real estate speculator of the future is wise to factor climate as a key consideration of investment and Climate Gentrification a key opportunity for financial return. Governments and social justice organizations may choose to examine the same conditions in addressing the housing needs of vulnerable populations.

Horizon 3 - A Positive Future

Harvesting the representation of the future in the present provides a clear path for disclosure and risk in the future. The the greatest opportunity for future wealth growth and managements exists within the psychological awareness of populations to be clear about climate change and the science behind it. Figure 19 offers a very clear understanding of the diverse non-scientific uses of the term climate change. As a result, confusion in the population is very understandable. The opportunity for all communicators and individuals is to move toward a scientific definition of climate change as a risk and resilience valuation lens. In ancient civilizations the stars and the tides were incredible mysteries which were explained through mythology. Today Science offers a clear explanation of the atmospheric performance and geologic reality of life on earth. It is these ideas, Scientific principles, upon which North American homeowners should shift their perceptions of climate-risk and property protection.

The responses of governments about climate-risk pressures are clear and offer positive examples for industry to follow. The response from insurance industry is clear and proactive in declaring climate-risk. These examples of future best practices emerging in the present marketplace make clear that home owners have opportunity to steer the policies of municipalities in a proactive response to climate-risk. Municipalities and regional governments have an important role to play in protecting contents from climate-risk. Industry is a key participant in shifting homeowner understanding of climate-risk, and is exposed to potential losses and liabilities for non-disclosure which could affect real estate trading conditions in the marketplace.

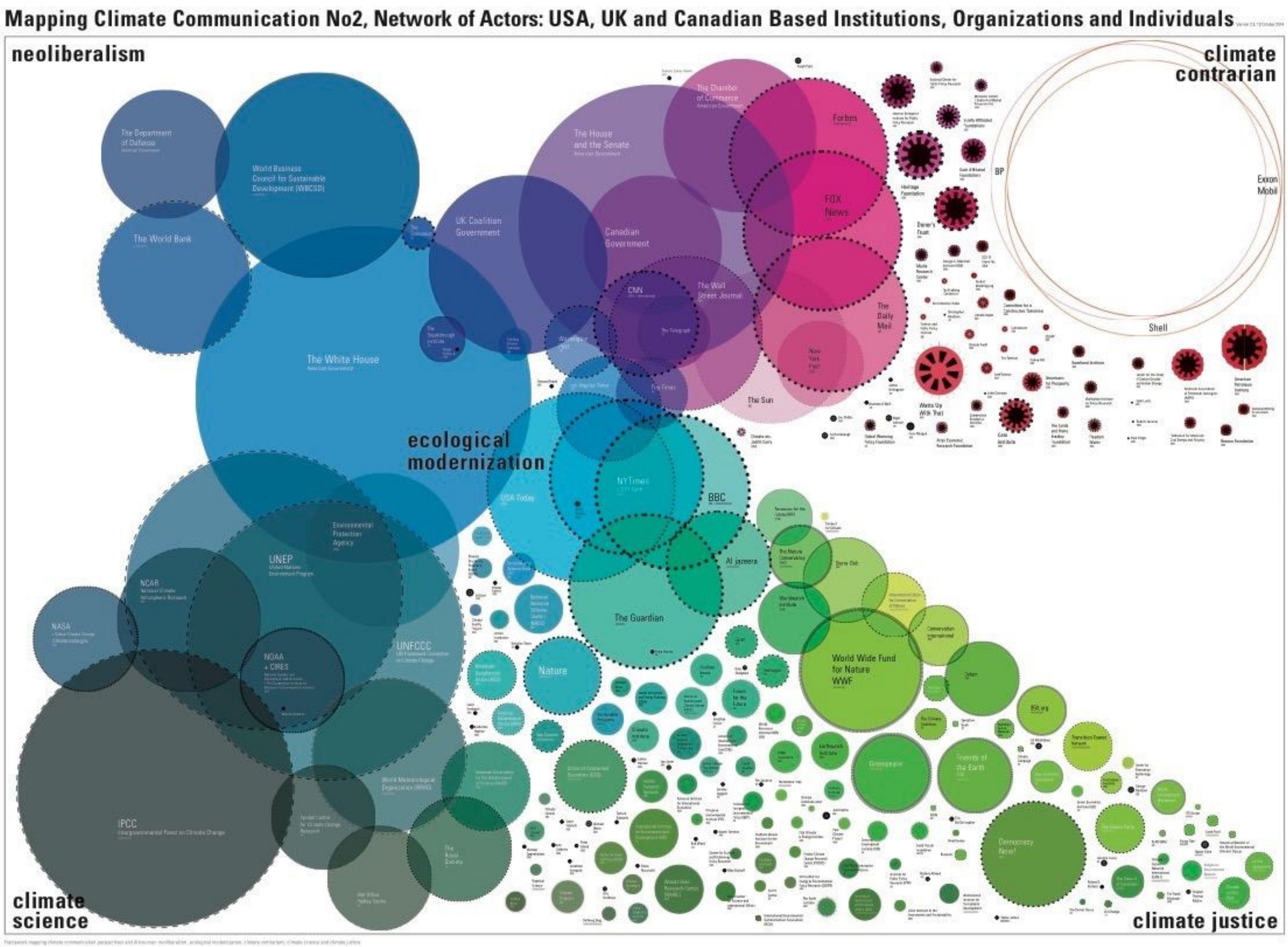


Figure 22: Mapping Climate Communications No. 2, Network of Actors - (Boehnert, J. 2016)

(IPCC). The upper right offers a glimpse of Climate Contrarian actors. It is worth noticing that the Canadian government is shown in the Climate Contrarian quadrant while The White house is shown to be both centrist and progressive, toward a scientific definition. The players within this robust analytical matrix of climate change communication have significant disparity in how they convey climate change, its certainty of scientific definition, and its certainty of outcomes. This disparity of meaning has created confusion in the public, political discourse and action to respond to the urgent impacts that scientist evidence will result from climate change. With the IPCC warning that 2030 brings a tipping point to catastrophic climate change, it seems only a matter of time that public acceptance, government action, and corporate compliance will adopt a scientific definition of climate change and acceptance of its unprecedented impacts on the lives of people.

Death, Taxes and Climate Change is the language of certainty about the existential future of property ownership in North America. While some may say that climate change is a natural phenomenon, there appears no evidence that severe weather will become less frequent, that insurance costs for catastrophic losses are decreasing, and that there is less property risk from more intense, frequent and damaging climate change impacts. Climate change and catastrophic-weather are scientific reality in 2030. When considering this future why not accept the science and act, immediately?

When scientific predictions are historic facts, will North American political debate become moot? Will confusion about the rhetoric about climate change become accepted fact? Will homeowners accept, understand and act upon the risk-impacts of climate change and the pragmatic need to respond to emerging risk? Imagine, that North Americans come to know that climate change is actuarial science, and that property values are susceptible to measurable and predictable climate change related value risk.

According to the IPCC Special report (April 2016) pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems (high confidence). These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options (medium confidence). With the increase of risk in all categories, and the urgent warning of tipping point by 2030 there is a clear indication that climate caused property impacts will continue in North American real estate markets, with deepening impacts in quality of life and loss of use impacts which are the foundation of property valuation.

Abandoning Atlantis

20 million people in the United States are estimated to be affected by sea-level rise by 2030 in selected regions that represent a range of sociodemographic characteristics and corresponding risks of vulnerability (Curtis, K. J., & Schneider, A. 2011). Sea level rise alone will impact approximately 6% of America's population who will be directly affected or displaced within 11 years. The economic cost for individual displaced migrants and their property losses have not been publicly researched, but the impacts are measurable and clear and offer an urgency today to respond decisively anticipating avoidable property, wealth and quality of life losses.

Place is part of identity as examined in the identity of place return of climate migrants to New Orleans. A difficult reconciliation unpacking cost-benefit argument about adaptation compared with migration. The value of stranded assets, and places of historical and human-psychological value needs to be understood along with with the cost and viability of adaptation. Small Island Developing States (SIDS) may not represent the home owning majority of Canadians and Americans who are at risk of suffering catastrophic property value loss, but there may be a lesson

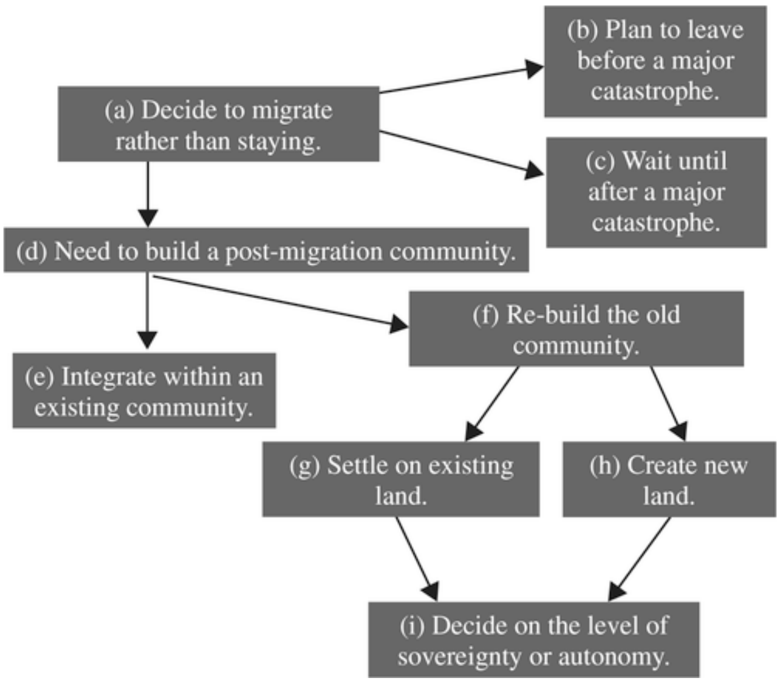


Figure 23: Abandoning Atlantis - Deciding to Stay or Migrate - Small Island Developing States - (Kelman, I. 2015)

to be learned from examining their plight. Figure 23 shows how SIDS in examining migration options (Kelman, I. 2015), the decision tree for SIDS may be applicable to many real estate markets across the continent.

There may in fact be value in investigating the cost of preservation and adaptation compared with the value of 'abandoning atlantis' in the face of unprecedented cost in preserving and protecting at risk communities in the US and Canada. Perhaps these considerations should be taken under advisement by the home owning public when choosing to remain in a location that is susceptible to higher risk. Similarly municipalities which will have predictably higher municipal tax burden, insurance cost, potentially devastating financial burdens may be wise to carefully consider the allocation of resilience spending and where to allow redevelopment. Communities and municipalities that are at risk might consider relocation as a lower cost, higher viability, option to investing untold qualities of money in fighting an unwinable battle against climate change impacts including sea-level rise.

The example of New York is an interesting one. Using sea-rise modelling researchers tested adaptation strategies and according to Scientific America "only one of the huge barrier solutions made the cut as an affordable strategy. Called "NJ-NY connect," it envisions constructing two storm barriers—one in the East River and another connect-ing Sandy Hook in New Jersey with the tip of the Rockaways in Queens, New York." (Marshall, 2014). The current investment strategy includes $500 Million in adaptation resilience planning (NYC Economic Development Corporation, March 2019). The most expensive solutions explored are estimated to cost 25.4 billion dollars. As a municipal taxpayer or landowner the real estate question that remains is about value. Is the value of use under such extreme and inevitable expenses significant enough to warrant the investment?

Political Shift

In 2030 will constituents and consumers shed their deference to government and corporations to create positive policy that offers resilience and quality of life to constituents? Government policy is shaped by Corporate interests "Yet in the name of the market, corporate libertarians actively advocate eliminating government regulation and point to the private cost savings for consumers while ignoring the social and environmental consequences for the broader society." (Korten, D. C. 1998). The consequence is that the 2016 U.S. national election promises to be of historic importance in our nation's and the world's efforts to deal with human-caused climate change. (Dunlap, R. E., McCright, A. M., & Yarosh, J. H. 2016).

The political divide on climate change will inevitably end. Based on the rate of growth in financial risk, personal property impacts, and observable lifetime shifts in weather the requirement for proactive government response to widespread adaptation is very likely to shift by 2030.

The 2030 time horizon is useful in understanding policy changes required to ensure that infrastructure toward 2030 are both resilient to climate changes and managed to reduce ongoing risks (World Health Organization, 2009). In the 2030 future there is a clear market understanding of climate risk and its relation to property value. Disclosure is central to property valuation and the collaboration and integration of human centred response solutions to creating public, private, and social resilience are probable future for both the home owning public and governments (Mees, H. 2017).

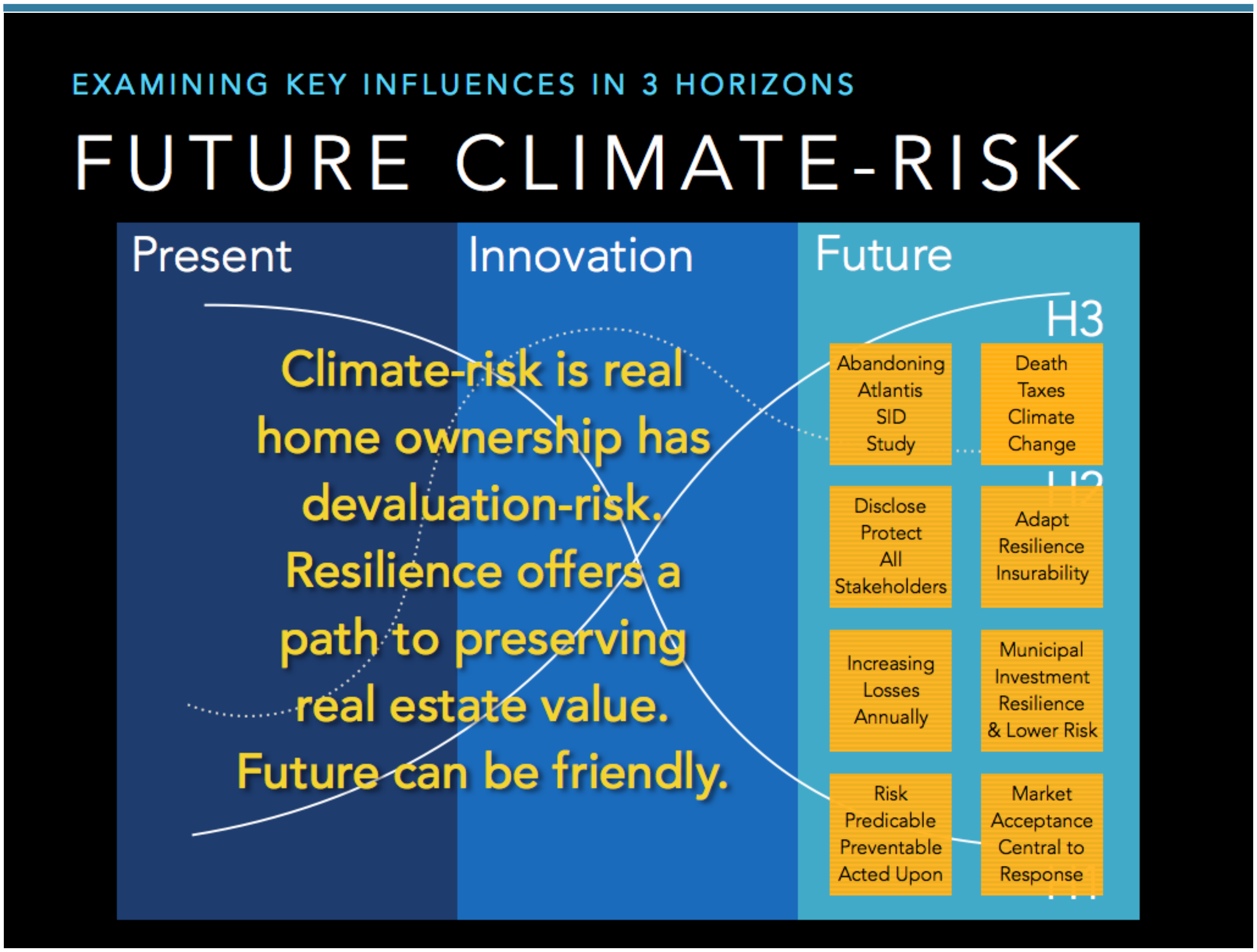


Figure 24: Third Horizon a Hopeful Future

Horizon 3 Summary

Examination of the third horizon provides a constellation of positive 2030 futures. This positivist outlook offers a hopeful future for the preservation of wealth and property use value in the face of emerging climate-risk increases. The end of marketplace climate confusion results in acceptance of the new certainties of life in 2030; Death, Taxes and Climate Change. If climate change denial is possible in 2019, it is irrefutably accepted in the everyday experience of North American homeowner by 2030. This marks a departure from the disparate attitudes towards climate change examined in Mapping Climate Communication No.2, Network of Actors (Boehnert, J. 2016) .

Scientific data suggests that climate change impacts will affect property owners across the continent. Also, there is no data that suggest that severe weather will occur less often with decreasing severity and frequency. There is only a simple clarity of understanding that climate change is affecting the behaviour of the oceans and atmosphere of the world, continuously into the future. These increased impacts will be felt in increased human suffering and financial losses. This will catalyze an acceptance of scientific data that informs policy and individual homeowner investment in resilience.

Abandoning Atlantis offers a sense of the plight of climate migrants the world over. The reality is that many Canadians and Americans will be in a position to choose to abandon properties which are no longer viable, have unjustifiable cost to retain or become inaccessible. The cost of resilience may be a cost that is financially unviable or the property condition unliveable.

In 2030 climate change will be a scientific term, devoid of rhetoric and depoliticized. Resilience will be the centre point of response to damaging weather systems of the world. In the 2030 future there is a clear understanding of climate risk and its relation to property value. Disclosure is central to property valuation. Collaboration and integration of human centred response solutions to creating public, private, and social resilience are probable future realities for both the home owning public and governments (Mees, H. 2017). As such, home valuation in 2030 will measure disclosed of hazard risk, local weather patterns, site level resilience, local infrastructure resilience, and regional capacity to respond.

The strongest point of resilience that has the capacity to emerge from these evolutions, may be the social capacity of people to be a primary ingredient in reduced climate impacts and accelerated recovery.

Conclusions

Home owners across the continent have suffered from negative property value impacts from climate-risk. Examination of the past and present market conditions demonstrates a negative value impact for properties affected directly and indirectly by a wide variety of climate-risk. The first horizon offers a constellation of market research which evidences a marketplace that is in denial about the negative valuation of climate-hazard-risk. Hedonic studies demonstrate that no mater the risk or the level of marketplace complacency, property that is directly or indirectly affected by climate change is likely to suffer value losses, and potentially lasting stigma. The result of these risk is diminished wealth and quality of life.

Some markets show examples of how home owners are protecting property valuation, through disclosure and resilience practices. These practices can reduce the risk assumed by unknowing purchasers, and make at risk properties more sellable. Property-level resilience investment can preserve value for homeowners against climate-risk, and municipal resilience investment can reduce risk to property at a neighbourhood and regional level.

Hopeful examples from Calgary, California, Edmonton and North Carolina exemplify how the housing market can disclose risk and integrate climate hazard into the real estate sales process. For many climate-risk impacts, property level resilience improvements can preserve value in the face of risk while improving the human capacity to respond. As an example the introduction of retrofit engagement programs like Firewise, has resulted in both lower susceptibility of property to wildfire and stronger capacity to respond from residents. The Institute for Catastrophic Loss Reduction (ICLR) offer home owner site-level and municipal guides to create resiliency at home and in community. Each of these examples offers a pathway to the preservation of market value, wealth and quality of life for homeowners.

Homeowners need to develop an understanding that property value risks are knowable, predictable and in some cases preventable. Difficult times are on the horizon for many property owners in North America. Climate change has emerged as an unstoppable reality of life today and into the future, and it will impact tens of millions of North American homeowners. The new framework of certainties about life are: Death, Taxes, and Climate Change. The future holds clarity for the acceptance of 'climate change' as a scientific term and the end of debate and ambivalence about climate-risk. Some communities will have to consider 'Abandoning Atlantis' as climate hazards make some real estate impossible to preserve and use. If it is conceivable that an island nation that finds its land overwhelmed by ocean be abandoned by its people, so too might we consider parts of the North American real estate market best abandoned, like Atlantis.

Stable real estate markets can emerge through the integration of best in class property and municipal resilience investments coupled with time of sale climate-risk disclosure. The cost of remaining confused about the certainty of climate science and its impact on property valuation is measured in billions of dollars of uninsured real estate value losses. The losses will be borne by people, whose lives may be displaced, and who's wealth will be eroded.

This study has focussed on reviewing specific weather and climate-risk impacts related to climate change for residential and recreational real estate in North America. There are some very significant impacts which are not reviewed in this study. They include the local economic impacts of recovery and future stability of markets, and regional infrastructure and power system resilience.

This study reveals the potential for positive value impacts of individual property resilience improvements, such as non-flammable roof systems and buildings, overland flooding resilience, rapid recovery of social and service connections, improved building methods and more. Home owners can and should invest in making real estate resilient, ahead of the storm.

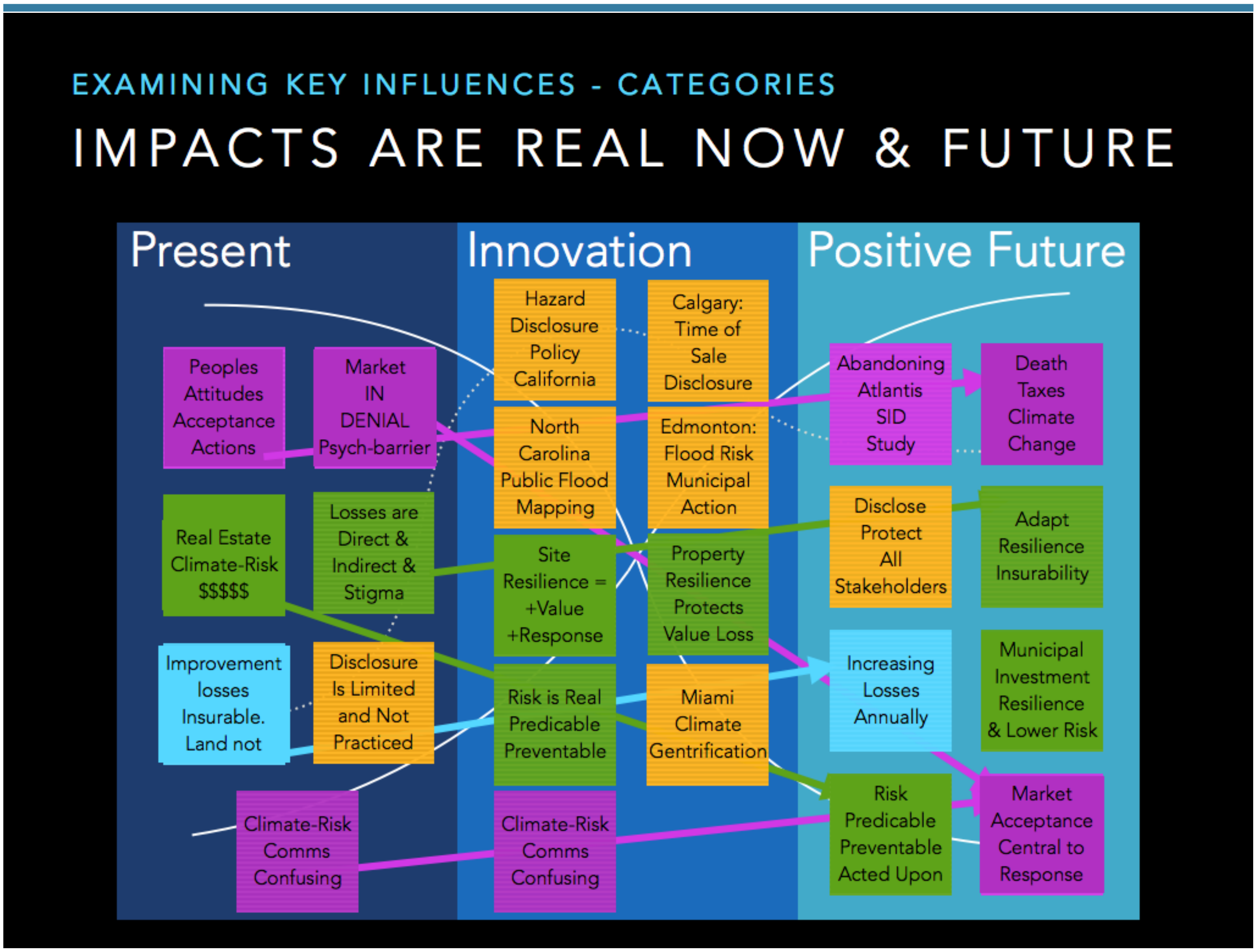


Figure 25: Examining the Future

Unforeseen catastrophe will be part of the emergent world of real estate climate-risk. The dynamical system of the world atmosphere and oceans that has been in relatively consistent balance for millions of years is now out of balance, and the meteorological impacts will be felt broadly and unexpectedly. There is an increasing probability that statistically-unlikely meteorological-catastrophes which will affect property use and value with greater frequency, and severity across North America and around the world. For this reason all real estate markets should include resilience as a future status quo for climate-risk amelioration. It is clear that the weather systems of the past are not predictive of the weather patterns of the future.

The Need for SERVICE DESIGN RESEARCH applied to Home Owner Engagement and Climate-Risk Response

This investigation reveals a need for human centred design researchers to develop a framework for more effective service delivery and communication effectiveness targeted to homeowners. Three specific areas of investigation are recommended:

A. discovery of optimal effective disclosure methods, tools and regulation within the real estate sales process
B. creation of municipal and homeowner integrated proactive and responsive resilience programming
C. development of response and recovery programs geared to 'learning from disaster' in order to prepare better for future events

Service Design Research (SDR) is suggested as a means of bringing the 'marketplace in denial' together with the real property climate-risk that threatens the wealth and welfare of North American homeowners.

The paradox of valuation coupled with understanding the complexity of human psychology and denial are central to helping home owners to embrace the challenging market obstacles presented by climate-risk. Market-wide engagement and user generated solutions through design research is of utmost importance. Service Design Research provides opportunities for constituent engagement and political championing of homeowner generated communication innovations. After examining documented complexity related to the market psychology of climate-risk, a Human Centred Design Research approach to hazard-communication and climate communication is a key recommendation for improving effectiveness of acceptance of risk and homeowner-action. This is an urgent area of study to be undertaken in order to mitigate property and population impacts from increased event intensity and frequency and the devastating financial and quality of life cost to North American homeowners.

Caveat Emptor and Climate-Risk

The unconscionable dilution of the scientific definition by all stakeholders in the face of the real and true scientific climate change impacts is remarkable. Changing climate is increasing measurable catastrophic property loss annually across the continent. There is no excuse for corporations, media and governments to be unclear in communicating the scientific facts about climate change, and property related climate-risk.

Flood, wind, drought, wildfire and sea-level rise are impacting populations and property values across North American markets. This direct impact on individual homeowners and their families offers a new framework for the definition of climate change. If a central theme to real estate transaction is caveat emptor - 'buyer beware'- the marketplace must be truthful and fact-based in its disclosure to the homeowner. American or Canadian homeowners deserve to be enabled to respond to the true and urgent threat that climate-risk poses to property values based on disclosure of facts related to the use and disruption of use of real property.

Buyers need to advocate for themselves in demanding scientific climate-risk data from the housing marketplace. The homeowner has the most financial risk associated with climate impacts. The demand for disclosure for climate-risk is an important precursor to caveat emptor, empowering the homeowner to understand, accept and respond to climate-risk and resilience in the context of property ownership.

Introducing the Real Estate Climate-Risk Index - REC Index

Examination of the constellation of climate-risks that affects home ownership has revealed a clear need for an understandable market communication tool that provides home owners with a property valuation climate-risk assessment. This proposed tool offers a simple and understandable climate-risk index assessment. It is like a Walk Score for climate-risk. This index is a calculator that allows anyone to generate a climate-risk assessment of a subject property with singular or multiple risk vectors. Introducing the Real Estate Climate-Risk Index (REC Index), a disclosure and resilience tool for protecting home ownership in North America.

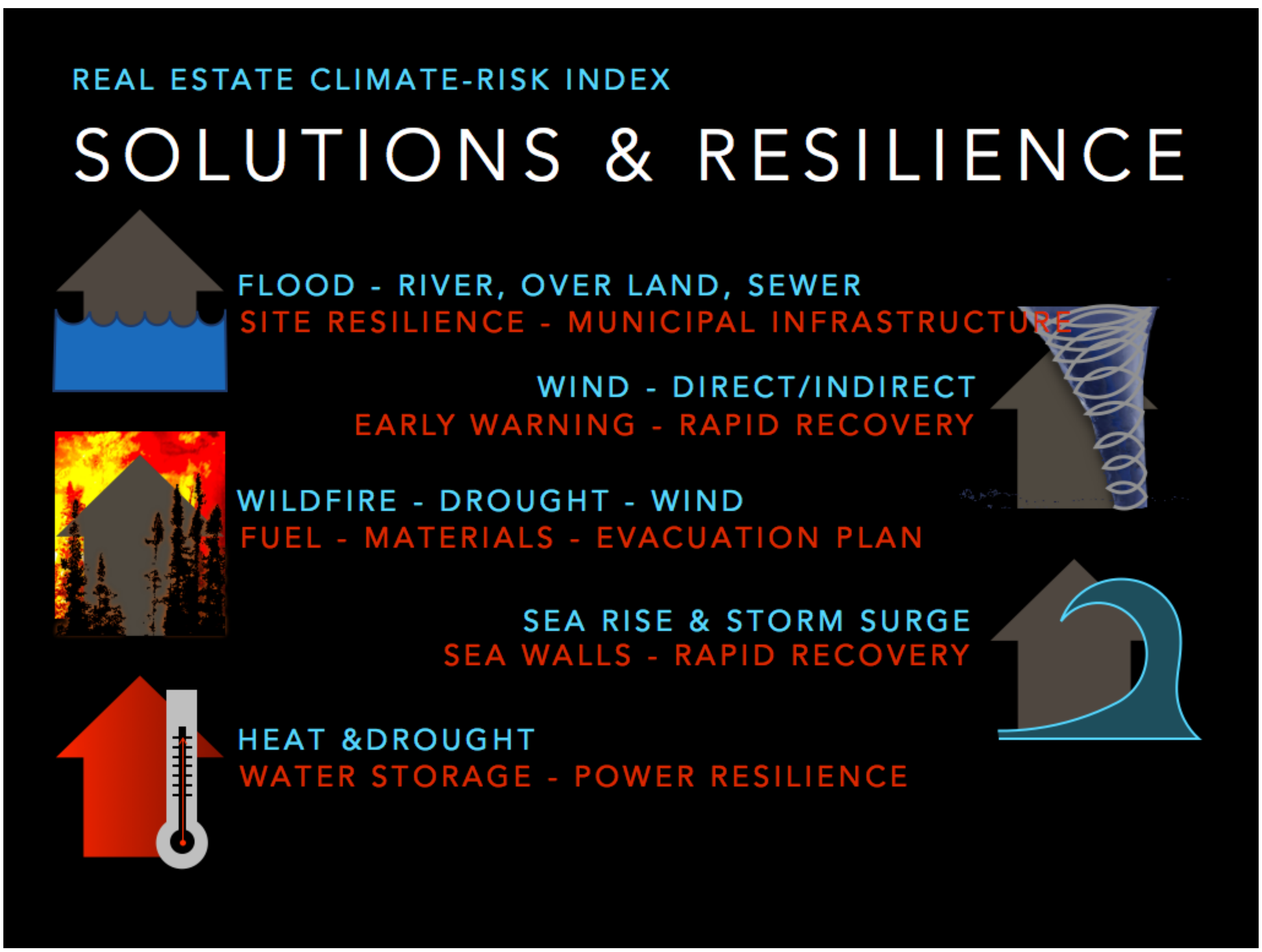
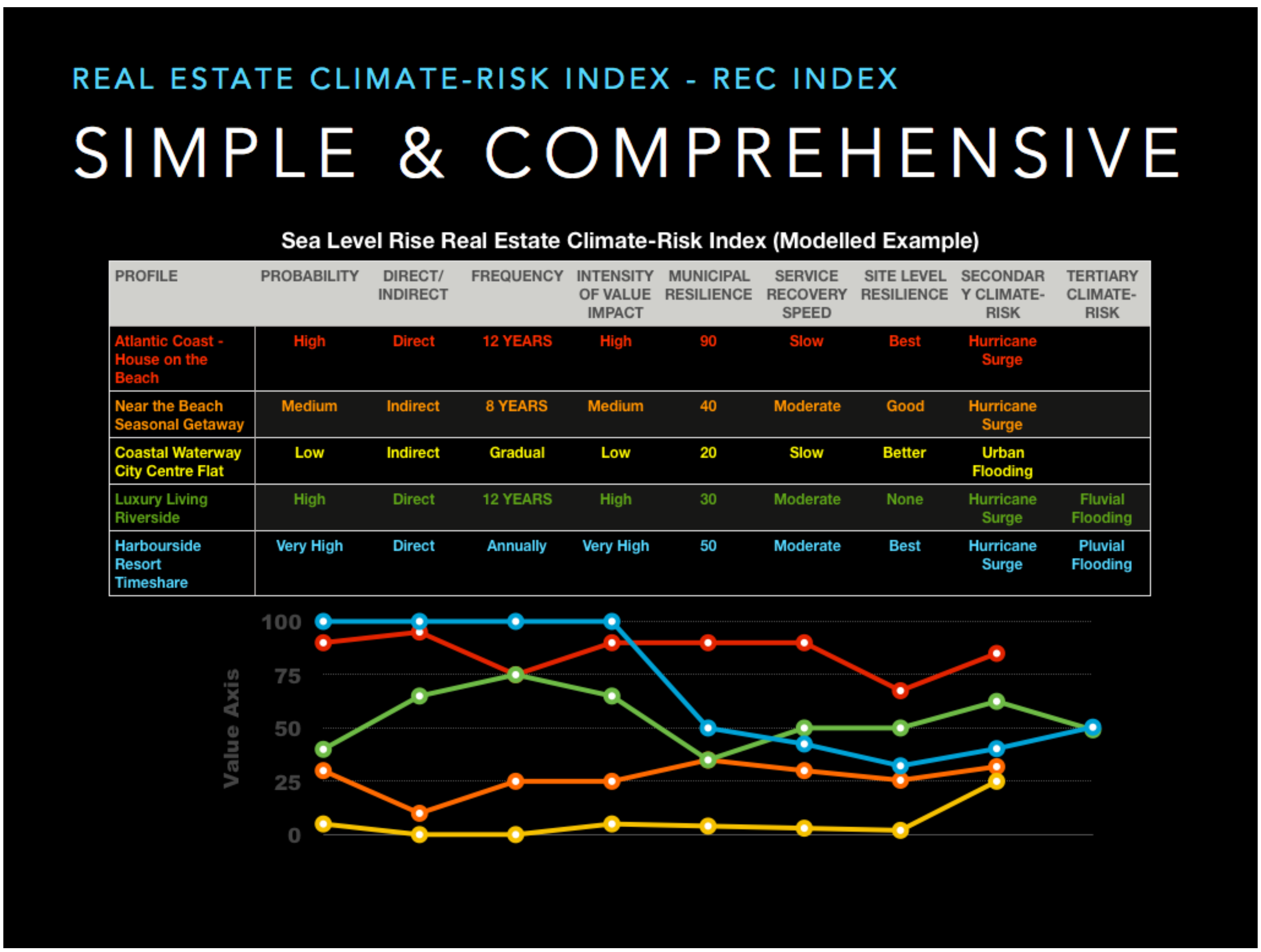


Figure 26: Real Estate Climate-Risk Index - Solutions & Resilience

Building on the knowable, predictable, preventable, research outcomes from the 3 horizon examination, the REC Index is a solution that offers anyone in the supply chain of property ownership with a method for climate-risk evaluation. The simple equation might look like this: ((Probability of risk-event) X (Probable frequency of event) X (Compounding Risk Secondary Vector (Tertiary vector…etc)) X (Severity of risk)) / ((Site level resilience) X (municipal resilience) X (regional resilience)) = (REC Index). This calculation may be used to examine loss of use, cost of recovery potentials and to project loss of property valuation. This can be utilized to help buyers, lenders and insurers to examine climate-risk and resilience impacts to property value (Figure 27).



PROFILE	PROBABILITY	DIRECT/ INDIRECT	FREQUENCY	INTENSITY OF VALUE IMPACT	MUNICIPAL RESILIENCE	SERVICE RECOVERY SPEED	SITE LEVEL RESILIENCE	SECONDARY CLIMATE-RISK	TERTIARY CLIMATE-RISK
Atlantic Coast - House on the Beach	High	Direct	12 YEARS	High	90	Slow	Best	Hurricane Surge	
Near the Beach Seasonal Getaway	Medium	Indirect	8 YEARS	Medium	40	Moderate	Good	Hurricane Surge	
Coastal Waterway City Centre Flat	Low	Indirect	Gradual	Low	20	Slow	Better	Urban Flooding	
Luxury Living Riverside	High	Direct	12 YEARS	High	30	Moderate	None	Hurricane Surge	Fluvial Flooding
Harbourside Resort Timeshare	Very High	Direct	Annually	Very High	50	Moderate	Best	Hurricane Surge	Pluvial Flooding

Figure 27: Real Estate Climate-Risk Index Simple & Comprehensive Trans-Risk Measurement

Figure 27 offers an example of how an investor might consider the value of multiple properties with very different risk profiles. In this example the risk and resilience measures can be compared by property type, to provide the marketplace with an understanding of relative risk and specific value impact risk category. This form of data representation can also provide a neighbourhood, or regional understanding of the value of resiliency measures implemented by government. Figure 28 offers a property level perspective. The High risk property is estimated to have higher interest and insurance cost, municipal tax burden, and periodic recovery cost relate to higher maintenance cost.

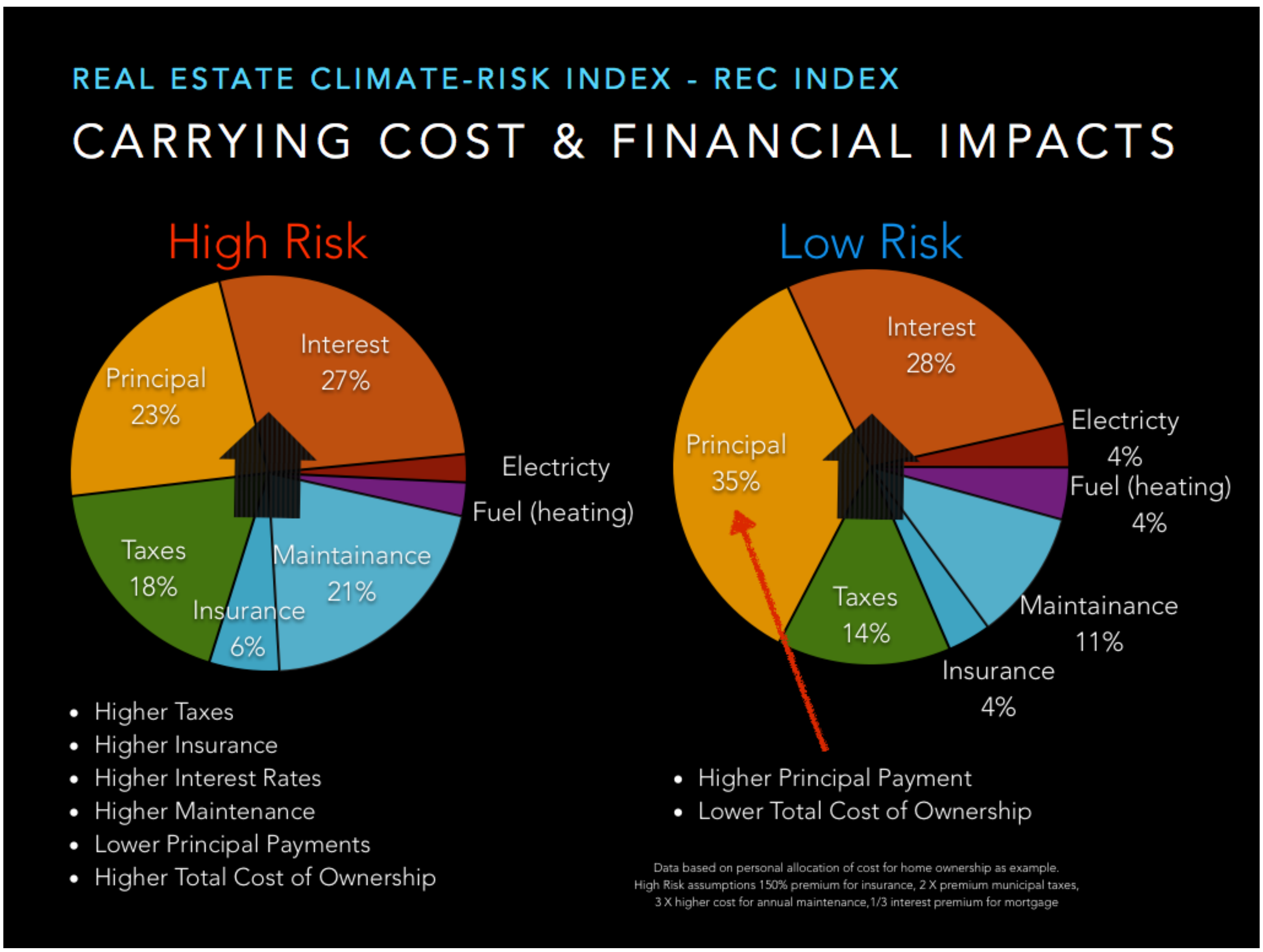


Figure 28: Real Estate Climate-Risk Index - Comparing Property Risk and Cost of Ownership

The Real Estate Cliamte-Risk Index can also offer a visual understanding of both climate-risk and climate-resilience in relation to specific properties in one visual indication. The REC Index provides a prospective view of how various components of risk and resilience can be understood when comparing different properties. A visual gradient can show increase risk sources and decrease in risk from resilience investments. While there is significant complexity in evaluating data inputs, they are understandable and can be made accessible in a property specific score.

Speculatively, The REC Index could offer a Walk-Score style rating for cost of living or total cost of ownership including the (de)valuation associated with climate-risk and resilience at property level and regionally.
The challenges of getting average homeowners in North America to take action in protecting their homes and cottages from personal property climate-risk is central to traversing obstacles of a marketplace in denial. Putting scientific climate-risk data together with resilience solutions provokes reconciliation of climate-risk in the context of real estate valuation and wealth preservation.

By combining climate science and resilience and self interested desire for property value preservation North Americans can manage wealth and optimize real estate investments.The required ingredients are overcoming denial combined with the generation of a willingness to evaluate and mitigate climate-risk through resilience measures. With clear, undebatable messaging and vigilant investment in resilience, municipalities and regional governments can preserve quality of life and property valuation across most markets.

BIBLIOGRAPHY

Aitsi-Selmi, A., Egawa, S., Sasaki, H., Wannous, C., & Murray, V. (2015). The Sendai framework for disaster risk reduction: Renewing the global commitment to people's resilience, health, and well-being. International Journal of Disaster Risk Science, 6(2), 164-176.

Balling, Robert, and Gregory Goodrich. "Spatial Analysis of Variations in Precipitation Intensity in the USA." Theoretical and Applied Climatology 104 (2011): 415–21. https://doi.org/10.1007/s00704-010-0353-0.

Barron, Sara, Glenis Canete, Jeff Carmichael, David Flanders, Ellen Pond, Stephen Sheppard, and Kristi Tatebe. "A Climate Change Adaptation Planning Process for Low-Lying, Communities Vulnerable to Sea Level Rise." Sustainability 4, no. 9 (September 2012): 2176–2208. https://doi.org/10.3390/su4092176.

Berke, Philip R., Jack Kartez, and Dennis Wenger. "Recovery after Disaster: Achieving Sustainable Development, Mitigation and Equity." Disasters 17, no. 2 (June 1993): 93–109.

Bin, Okmyung, and Stephen Polasky. "Effect of Flood Hazards on Property Values: Evidence Before and After Hurricane Floyd." Land Economics, 2004, 490–500.

Boehnert, Dr Joanna. "Data Visualisation Does Political Things." Loughborough University Institutional Repository, 2016, 21.

Buck, Steven, Maximilian Auffhammer, and David Sunding. "Land Markets and the Value of Water: Hedonic Analysis Using Repeat Sales of Farmland." American Journal of Agricultural Economics 96, no. 4 (July 1, 2014): 953–69. https://doi.org/10.1093/ajae/aau013.

Burrus, Robert T., Jr., J. Edward Graham Jr., William W. Hall, and Peter W. Schuhmann. "Home-Buyer Sentiment and Hurricane Landfalls." Appraisal Journal, 2009. Academic OneFile.

Carbon Lighthouse. "Inside the Hearts and Minds of Building Owners." Climate Solved. Accessed June 27, 2018. https://www.carbonlighthouse.com/category/podcasts/.

(CBC April 22,2019)
https://www.cbc.ca/news/canada/ottawa/gatineau-floods-ottawa-francois-legault-1.5106522

Chamlee-Wright, Emily, and Virgil Henry Storr. "'There's No Place like New Orleans': Sense of Place and Community Recovery in the Ninth Ward after Hurricane Katrina." Journal of Urban Affairs 31, no. 5 (December 2009): 615–34. https://doi.org/10.1111/j.1467-9906.2009.00479.x.

Chopik, Chris. "Flood is a real concern for property valuation." REM Online, Feb 12, 2018. https://www.remonline.com/flood-real-concern-property-valuation/

City of Edmonton. "City-Wide Flood Mitigation Strategy." City of Edmonton Open Data Portal, 2016. https://data.edmonton.ca/stories/s/City-Wide-Flood-Mitigation-Strategy/suej-ppxq/.

City of Edmonton. "What is the Edmondon Declaration?" City of Edmonton website, 2018. https://www.edmonton.ca/city_government/environmental_stewardship/change-for-climate-edmonton-declaration.aspx

Cook, B. I., Ault, T. R., & Smerdon, J. E. (2015). Unprecedented 21st century drought risk in the American Southwest and Central Plains. Science Advances, 1(1), e1400082.

Curtis, Katherine J., and Annemarie Schneider. "Understanding the Demographic Implications of Climate Change: Estimates of Localized Population Predictions under Future Scenarios of Sea-Level Rise." Population and Environment 33, no. 1 (September 2011): 28–54. https://doi.org/10.1007/s11111-011-0136-2.

Cutting, Robert H., Lawrence B. Cahoon, and Jack C. Hall. "Location, Location, Location Should Be Environment, Environment, Environment: A Market-Based Tool to Simplify Environmental Considerations in Residential Real Estate." Golden Gate University Environmental Law Journal 6 (2013 2012): 83.

Dai, A. "Increasing Drought under Global Warming in Observations and Models." Nature Climate Change 3 (2012): 52–58. https://doi.org/10.1038/nclimate1633.

———. "Recent Climatology, Variability, and Trends in Global Surface Humidity." Journal of Climate 19 (2006): 3589–3606. https://doi.org/10.1175/JCLI3816.1.

Dlugolecki, Andrew. "The Cost of Extreme Events in 2030," July 16, 2007, 44.

Donovan, Geoffrey, Patricia Champ, and David Butry. "Wildfire Risk and Housing Prices: A Case Study from Colorado Springs." Land Economics 83 (2007). https://doi.org/10.3368/le.83.2.217.

Dutton, John A. "Opportunities and Priorities in a New Era for Weather and Climate Services." American Meteorological Society, no. September 2002 (2002). https://journals.ametsoc.org/doi/pdf/10.1175/1520-0477-83.9.1303.

Elsner, James B., Tyler Fricker, and Zoe Schroder. “Increasingly Powerful Tornadoes in the United States.” Geophysical Research Letters 46, no. 1 (2019): 392–98. https://doi.org/10.1029/2018GL080819.

Eves, Chris. “The Long-term Impact of Flooding on Residential Property Values.” Property Management 20, no. 4 (October 1, 2002): 214–27. https://doi.org/10.1108/02637470210444259.

Ewing, Bradley T., Jamie B. Kruse, and Yongsheng Wang. “Local Housing Price Index Analysis in Wind-Disaster-Prone Areas.” Natural Hazards 40, no. 2 (January 2, 2007): 463–83. https://doi.org/10.1007/s11069-006-9005-1.

F. W. Zwiers, M. D. Flannigan, N. P. Gillett, and A. J. Weaver. “Detecting the Effect of Climate Change on Canadian Forest Fires.” Geophysical Research Letters 31, no. 18 (April 1, 2019). https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2004GL020876.

Federal Emergency Management Agency (FEMA). “Public Survey Findings on Flood Risk,” September 14, 2018. https://www.fema.gov/public-survey-findings-flood-risk.

Feltemate, Blair, and Jason Thistlethwaite. “Climate Change Adaptation: A Priorities Plan for Canada.” Intact Centre for Climate Adaptation, 2012. https://www.intactcentre.ca/wp-content/uploads/docs/Climate%20Change%20Adaptation%20-%20A%20Priorities%20Plan%20for%20Canada%20(2012).pdf.

Goodman, Laurie S., and Christopher Mayer. “Homeownership and the American Dream.” The Journal of Economic Perspectives 32, no. 1 (2018): 31–58.

Gopalakrishnan, Sathya, Martin D Smith, Jordan M Slott, and A Brad Murray. “The Value of Disappearing Beaches: A Hedonic Pricing Model with Endogenous Beach Width,” 2009, 33.

Environment and Climate Change Canada. “Key Issues - Climate Change.” Government of Canada, November 2015. https://www.canada.ca/en/environment-climate-change/corporate/transparency/briefing/key-issues-climate-change.html#s5

Hallegatte, Stéphane, Jean-Charles Hourcade, and Philippe Ambrosi. “Using Climate Analogues for Assessing Climate Change Economic Impacts in Urban Areas.” Climatic Change 82, no. 1 (May 1, 2007): 47–60. https://doi.org/10.1007/s10584-006-9161-z.

Heilizer, Anthony. Method and system for insuring the future value of real property. United States, filed July 11, 2002, and issued January 30, 2003. https://patents.google.com/patent/US20030023462A1/en.

ICLR. “Homeowner.” ICLR (blog), February 20, 2019. https://www.iclr.org/homeowner/.
Karl, T.R., J. T. Melillo, and T. C. Peterson. Global Climate Change Impacts in the United States. New York, NY: Cambridge University Press, 2009.

IPCC. “Global Warming of 1.5°C: Summary for Policymakers.” Intergovernmental Panel on Climate Change, 2018. https://www.ipcc.ch/sr15/.

Keenan, Jesse M, Thomas Hill, and Anurag Gumber. “Climate Gentrification: From Theory to Empiricism in Miami-Dade County, Florida.” Environmental Research Letters 13, no. 5 (May 1, 2018): 054001. https://doi.org/10.1088/1748-9326/aabb32.

Keiter, Robert B. “Wildfire Policy, Climate Change, and the Law.” Texas A&M Journal of Property Law 1 (2014 2012): 87.

Kelman, Ilan. “Climate Change and the Sendai Framework for Disaster Risk Reduction.” International Journal of Disaster Risk Science 6, no. 2 (June 2015): 117–27. https://doi.org/10.1007/s13753-015-0046-5.

———. “Difficult Decisions: Migration from Small Island Developing States under Climate Change.” Earth’s Future 3, no. 4 (2015): 133–42. https://doi.org/10.1002/2014EF000278.

Kleist, Michael R., and Douglas G. Dempster. System and method for assessing the people and property impact of weather. United States, filed March 31, 2005, and issued February 20, 2007. https://patents.google.com/patent/US7181346B1/en.

Korten, David C. “When Corporations Rule the World,” n.d., 5.

Kramer, H. Anu, Miranda H. Mockrin, Patricia M. Alexandre, Susan I. Stewart, and Volker C. Radeloff. “Where Wildfires Destroy Buildings in the US Relative to the Wildland–Urban Interface and National Fire Outreach Programs.” International Journal of Wildland Fire 27, no. 5 (2018): 329. https://doi.org/10.1071/WF17135.

Kunkel, K.E., T. R. Karl, H. Brooks, J. Kossin, J. Lawrimore, D. Arndt, L. Bosart, et al. “Monitoring and Understanding Trends in Extreme Storms: State of Knowledge.” Bulletin of the American Meteorological Society 94 (2013). https://doi.org/10.1175/BAMS-D-11-00262.1.

Kunkel, K.E., L. E. Stevens, S. E. Stevens, L. Sun, E. Janssen, D. Wuebbles, and J. G. Dobson. “Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 9. Climate of the Contiguous United States. NOAA Technical Report NESDIS 142-9,” 2013.

Leiserowitz, Anthony. “Edmonton Declaration Asks Cities to Lead» Yale Climate Connections.” Yale Climate Connections (blog), February 8, 2019. https://www.yaleclimateconnections.org/2019/02/edmonton-declaration-asks-cities-to-lead/.

Leiserowitz et al. “Global Warming’s Six Americas, May 2011.” Yale University and George Mason University, 2011. http://www.earthtosky.org/content/course-content/2012-mini-course/Knowledege_of_Audience/SixAmericas-May2011.pdf.

Lindsay, Tina, and Heather McGrath. “Federal Flood Mapping Activities and Web-Based Flood Risk Assessment (ER2).” March 5, 2019. https://conservationontario.ca/fileadmin/pdf/conservation_authorities_tech_transfer/Tech-Transfer2019_2_McGrath_and_Lindsay_Federal_Flood_Mapping_Update.pdf.

Loomis, John. “Do Nearby Forest Fires Cause a Reduction in Residential Property Values?” Journal of Forest Economics 10, no. 3 (November 2, 2004): 149–57. https://doi.org/10.1016/j.jfe.2004.08.001.

Marshall, Christa. “Massive Seawall May Be Needed to Keep New York City Dry.” Climate Wire, May 5, 2014. https://www.scientificamerican.com/article/massive-seawall-may-be-needed-to-keep-new-york-city-dry/

Mees, Heleen. “Local Governments in the Driving Seat? A Comparative Analysis of Public and Private Responsibilities for Adaptation to Climate Change in European and North-American Cities.” Journal of Environmental Policy & Planning 19, no. 4 (July 4, 2017): 374–90. https://doi.org/10.1080/1523908X.2016.1223540.

Milken Institute. “Financial Innovations for Catastrophic Risk: Cat Bonds and Beyond.” Financial Innovations Lab Report, April 2008. https://assets1c.milkeninstitute.org/assets/Publication/InnovationLab/PDF/FnclInnovsCat-BondsApr08.pdf.

Mills, Evan. “A Global Review of Insurance Industry Responses to Climate Change.” Geneva Papers on Risk & Insurance - Issues & Practice 34, no. 3 (July 2009): 323–59. https://doi.org/10.1057/gpp.2009.14.

———. “Availability and Affordability of Insurance Under Climate Change.” U.S. Department of Energy, 2005, 43.

Mishra, Sasmita, Sanjoy Mazumdar, and Damodar Suar. “Place Attachment and Flood Preparedness.” Journal of Environmental Psychology 30, no. 2 (June 1, 2010): 187–97. https://doi.org/10.1016/j.jenvp.2009.11.005.

Moel, H de, and J van Alphen. “Flood Maps in Europe – Methods, Availability and Use.” Nat. Hazards Earth Syst. Sci., 2009, 13.

Mojtahedi, S. M. H., and B. L. Oo. “Coastal Buildings and Infrastructure Flood Risk Analysis Using Multi-Attribute Decision-Making.” Journal of Flood Risk Management 9, no. 1 (2016): 87–96. https://doi.org/10.1111/jfr3.12120.

Monti, Alberto, and Claudio Tagliapietra. “Tracking Insurance Industry Exposures to CAT Risks and Quantifying Insured and Economic Losses in the Aftermath of Disaster Events: A Comparative Survey.” OECD, nd., 30.

Moser, Susanne C. “Impact Assessments and Policy Responses to Sea-Level Rise in Three US States: An Exploration of Human-Dimension Uncertainties.” Global Environmental Change 15, no. 4 (December 2005): 353–69. https://doi.org/10.1016/j.gloenvcha.2005.08.002.

Mueller, Julie, John Loomis, and Armando González-Cabán. “Do Repeated Wildfires Change Homebuyers’ Demand for Homes in High-Risk Areas? A Hedonic Analysis of the Short and Long-Term Effects of Repeated Wildfires on House Prices in Southern California.” The Journal of Real Estate Finance and Economics 38, no. 2 (February 1, 2009): 155–72. https://doi.org/10.1007/s11146-007-9083-1.

Mukherjee, Monobina, and Kurt Schwabe. “Irrigated Agricultural Adaptation to Water and Climate Variability: The Economic Value of a Water Portfolio.” American Journal of Agricultural Economics 97, no. 3 (April 1, 2015): 809–32. https://doi.org/10.1093/ajae/aau101.

Mutch, Robert W., Michael J. Rogers, Scott L. Stephens, and A. Malcolm Gill. “Protecting Lives and Property in the Wildland–Urban Interface: Communities in Montana and Southern California Adopt Australian Paradigm.” Fire Technology 47, no. 2 (April 2011): 357–77. https://doi.org/10.1007/s10694-010-0171-z.

National Oceanic and Atmospheric Administration (NOAA). “Hurricane Costs: Fast Facts,” nd. https://coast.noaa.gov/states/fast-facts/hurricane-costs.html.

———. “Tutorial for Sea Level Rise Viewer: Local Scenarios Tab.” Digital Coast: Office for Coastal Management, nd. https://coast.noaa.gov/elearning/localscenarios/.

Niittyvirta, Pekka, and Timo Aho. Lines (57° 59´N, 7° 16´W). 2018. http://www.niittyvirta.com/all-works/.

North Carolina Department of Public Safety. “NC Floodplain Mapping Program.” North Carolina Department of Public Safety, n.d. https://flood.nc.gov/ncflood/mappingprogram.html

NYC Economic Development Corporation. “Lower Manhattan Climate Resilience Study,” March 2019. https://www.nycedc.com/sites/default/files/filemanager/Projects/LMCR/Final_Image/Lower_Manhattan_Climate_Resilience_March_2019.pdf.

October 14, Elise Stolte Updated:, and 2016. “City to Release Neighbourhood Flood Maps after Postmedia Wins Appeal | Edmonton Journal,” October 14, 2016. https://edmontonjournal.com/news/local-news/city-loses-battle-to-keep-edmonton-flood-maps-secret.

Oyler, Melissa. “Take The Stairs: Elevators Become Traps During Floods And Hurricanes And There’s Little Regulation.” Bisnow National, 0205 2019. https://www.bisnow.com/national/news/hotel/could-a-small-device-have-prevented-womans-drowning-death-in-elevator-93740.

Paveglio, Travis B., Matthew S. Carroll, Amanda M. Stasiewicz, and Catrin M. Edgeley. “Social Fragmentation and Wildfire Management: Exploring the Scale of Adaptive Action.” International Journal of Disaster Risk Reduction 33 (February 2019): 131–41. https://doi.org/10.1016/j.ijdrr.2018.09.016.

Peterson, T., R. Heim, R. Hirsch, D. Kaiser, H. Brooks, N. Diffenbaugh, R. Dole, et al. “Monitoring and Understanding Changes in Heat Waves, Cold Waves, Floods and Droughts in the United States: State of Knowledge.” Bulletin of the American Meteorological Society 94 (2013): 821–34. https://doi.org/10.1175/BAMS-D-12-00066.1.

Posey, John, and William H. Rogers. “The Impact of Special Flood Hazard Area Designation on Residential Property Values.” Public Works Management & Policy 15, no. 2 (October 1, 2010): 81–90. https://doi.org/10.1177/1087724X10380275.

Price, Owen F., and Ross A. Bradstock. “The Efficacy of Fuel Treatment in Mitigating Property Loss during Wildfires: Insights from Analysis of the Severity of the Catastrophic Fires in 2009 in Victoria, Australia.” Journal of Environmental Management 113 (December 30, 2012): 146–57. https://doi.org/10.1016/j.jenvman.2012.08.041.

Proceedings from the 2016 UR Forum. “Understanding Risk: Building Evidence for Change.” Understanding Risk Forum 2016, 2016. https://understandrisk.org/wp-content/uploads/UR-venice-proceedings.pdf.

Pryce, Gwilym, and Yu Chen. “Flood Risk and the Consequences for Housing of a Changing Climate: An International Perspective.” Risk Management 13, no. 4 (2011): 228–46.

Puleo, Thomas J. and Sivak, Henry. “The Ambivalence of Catastrophe.” The Geographical Review, 103 (4): 458 - 468, October, 2013. https://www.academia.edu/6812291/Introduction_the_ambivalence_of_catastrophe

Rehdanz, Katrin. “Hedonic Pricing of Climate Change Impacts to Households in Great Britain.” Climatic Change 74, no. 4 (February 1, 2006): 413–34. https://doi.org/10.1007/s10584-006-3486-5.

Reichert, Alan, Michael Small, and Sunil Mohanty. “The Impact of Landfills on Residential Property Values.” Journal of Real Estate Research 7, no. 3 (January 1, 1992): 297–314. https://doi.org/10.5555/rees.7.3.g168q57862h2t2ht.

Ross, Tom, and Neal Lott. “A Climatology of 1980-2003 Extreme Weather and Climate Events.” National Climatic Data Center Technical Report, December 2003. https://repository.library.noaa.gov/view/noaa/13831.
Samarasinghe, Oshadhi, and Basil Sharp. “Flood Prone Risk and Amenity Values: A Spatial Hedonic Analysis.” Australian Journal of Agricultural and Resource Economics 54, no. 4 (2010): 457–75. https://doi.org/10.1111/j.1467-8489.2009.00483.x.

Santer, B.D., C. Mears, F. J. Wentz, K. E. Taylor, P. J. Gleckler, T. M. L. Wigley, T. P. Barnett, et al. “Identification of Human-Induced Changes in Atmospheric Moisture Content.” Proceedings of the National Academy of Sciences 104 (2007): 15248–53. https://doi.org/10.1073/pnas.0702872104.

Sartre, J. P. (2012). *Being and nothingness*. Open Road Media.

Schlenker, Wolfram, W. Michael Hanemann, and Anthony C. Fisher. “Water Availability, Degree Days, and the Potential Impact of Climate Change on Irrigated Agriculture in California.” Climatic Change 81, no. 1 (March 1, 2007): 19–38. https://doi.org/10.1007/s10584-005-9008-z.

———. “Will U.S. Agriculture Really Benefit from Global Warming? Accounting for Irrigation in the Hedonic Approach.” American Economic Review 95, no. 1 (March 2005): 395–406. https://doi.org/10.1257/0002828053828455.

Schmitz, Adrienne, Robert Chickering, and Urban Land Institute. Resort Development, 2008. http://public.eblib.com/choice/publicfullrecord.aspx?p=1664998.

Sharpe, Bill, Anthony Hodgson, Graham Leicester, Andrew Lyon, and Ioan Fazey. “Three Horizons: A Pathways Practice for Transformation.” Ecology and Society 21, no. 2 (June 28, 2016). https://doi.org/10.5751/ES-08388-210247.

Shrubsole, Dan. “Flood Management in Canada at the Crossroads.” Global Environmental Change Part B: Environmental Hazards 2, no. 2 (January 1, 2000): 63–75. https://doi.org/10.3763/ehaz.2000.0211.

Simmons, A.J., K. M. Willett, P. D. Jones, P. W. Thorne, and D. P. Dee. "Low-Frequency Variations in Surface Atmospheric Humidity, Temperature, and Precipitation: Inferences from Reanalyses and Monthly Gridded Observational Data Sets." Journal of Geophysical Research 115 (2010): 1–21. https://doi.org/10.1029/2009JD012442.

Simmons, Kevin M., Jamie Brown Kruse, and Douglas A. Smith. "Valuing Mitigation: Real Estate Market Response to Hurricane Loss Reduction Measures." Southern Economic Journal 68, no. 3 (2002): 660–71. https://doi.org/10.2307/1061724.

Smith, Adam B., and Richard W. Katz. "US Billion-Dollar Weather and Climate Disasters: Data Sources, Trends, Accuracy and Biases." Natural Hazards 67, no. 2 (June 2013): 387–410. https://doi.org/10.1007/s11069-013-0566-5.

Stetler, Kyle M., Tyron J. Venn, and David E. Calkin. "The Effects of Wildfire and Environmental Amenities on Property Values in Northwest Montana, USA." Ecological Economics 69, no. 11 (September 2010): 2233–43. https://doi.org/10.1016/j.ecolecon.2010.06.009.

Stribling, Dees. "Real Estate Market Sentiment Index: 1 In 5 Say Downturn Has Begun." Bisnow National, January 23, 2019. https://www.bisnow.com/national/news/economy/rclco-survey-finds-creeping-pessimism-in-cre-in-2019-97018.

Tanner, S. "Burning down the House: The Cost of Wildfires in Heavily Urbanized Areas," no. 2058-2018–5268 (2018): 27.

Terpstra, Teun. "Emotions, Trust, and Perceived Risk: Affective and Cognitive Routes to Flood Preparedness Behavior." Risk Analysis 31, no. 10 (2011): 1658–75. https://doi.org/10.1111/j.1539-6924.2011.01616.x.

Thoreau, H. D. (2006). *Walden*. Yale University Press.

Trapasso, Clare. "California Wildfires: Housing Markets Will Likely Feel Devastating Effects for Years." Real Estate. Real Estate News and Advice | Realtor.com®, October 12, 2017. https://www.realtor.com/news/trends/wildfires/.

Urban Land Institute. A Guide for Assessing Climate Change Risk. Washington, DC: Urban Land Institute, 2015. https://uli.org/wp-content/uploads/ULI-Documents/ULI-A-Guide-for-Assessesing-Climate-Change-Risk-final.pdf

U.S. Global Change Research Program (2009-). "Climate Change Impacts in the United States, Highlights: U.S. National Climate Assessment," 2014. http://heinonline.org/HOL/Page?handle=hein.usfed/clichimus0001&id=1&collection=usfed&index=usfed.

Vose, James M., James S. Clark, Charles H. Luce, and Toral Patel-Weynand. "Effects of Drought on Forests and Rangelands in the United States: A Comprehensive Science Synthesis." Washington, DC: U.S. Department of Agriculture, Forest Service, 2016. https://doi.org/10.2737/WO-GTR-93b.

Vose, Russell, Scott Applequist, Mark Bourassa, Sara Pryor, Rebecca Barthelmie, Brian Blanton, Peter Bromirski, et al. "Monitoring and Understanding Changes in Extremes: Extratropical Storms, Winds, and Waves." Bulletin of the American Meteorological Society in press (2013). https://doi.org/10.1175/BAMS-D-12-00162.1.

Wachinger, Gisela, Ortwin Renn, Chloe Begg, and Christian Kuhlicke. "The Risk Perception Paradox—Implications for Governance and Communication of Natural Hazards." Risk Analysis 33, no. 6 (2013): 1049–65. https://doi.org/10.1111/j.1539-6924.2012.01942.x.

Wang, M., and J. E. Overland. "A Sea Ice Free Summer Arctic within 30 Years?" Geophysical Research Letters 36 (2009): L07502. https://doi.org/10.1029/2009GL037820.

Warren, Fiona J, and Donald Stanley Lemmen, eds. Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation. Natural Resources Canada, 2014. https://www.nrcan.gc.ca/environment/resources/publications/impacts-adaptation/reports/assessments/2014/16309.

Wehner, M.F. "Very Extreme Seasonal Precipitation in the NARCCAP Ensemble: Model Performance and Projections." Climate Dynamics 40 (2013): 59–80. https://doi.org/10.1007/s00382-012-1393-1.

Westerling, A. L., and B. P. Bryant. "Climate Change and Wildfire in California." Climatic Change 87, no. 1 (March 1, 2008): 231–49. https://doi.org/10.1007/s10584-007-9363-z.

Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. "Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity." Science 313, no. 5789 (August 18, 2006): 940–43. https://doi.org/10.1126/science.1128834.

Willett, Eric, and Brett Dunlavey. "Building Opportunity: Mapping Gentrification and Investment across Opportunity Zones," February 7, 2019. http://www.rclco.com/advisory-opportunity-zones-gentrification-investment.

Willett, K.M., P. D. Jones, N. P. Gillett, and P. W. Thorne. "Recent Changes in Surface Humidity: Development of the HadCRUH Dataset." Journal of Climate 21 (2008): 5364–83. https://doi.org/10.1175/2008JCLI2274.1.

Williams, Geoff. “Will Climate Change Decrease Your Home’s Value?” US News & World Report, March 29, 2019. https://realestate.usnews.com/real-estate/articles/how-climate-change-could-impact-your-home-value.

World Health Organization. Summary and Policy Implications Vision 2030: The Resilience of Water Supply and Sanitation in the Face of Climate Change. Geneva: World Health Organization, 2009.

Wuebbles, D.J., G. Meehl, K. Hayhoe, T. Karl, K. Kunkel, B. Santer, M. Wehner, et al. “CMIP5 Climate Model Analyses: Climate Extremes in the United States.” Bulletin of the American Meteorological Society in press (2013). https://doi.org/10.1175/BAMS-D-12-00172.1.