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Climate Change Impact on the US Real Estate Market; with Particular Examination of the Sea Level Rise

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Affidavit

I hereby affirm that this Bachelor's Thesis represents my own written work and that I have used no sources and aids other than those indicated. All passages quoted from publications or paraphrased from these sources are properly cited and attributed.

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Abstract

Climate change is one of the most addressed topics in recent years. But, what is climate change, what are its consequences, and how does it affect the properties where people live and work, how does it affect real estate? This is what the study intends to explore through the topic of "Climate change impact on the US real estate market; with particular examination of the sea level rise". One of the main consequences of climate change is the increase in temperature, leading to increased melting of solid bodies of water such, glaciers, ice caps and snow causing the global sea level to rise. With many of the world's largest cities located in coastal regions, this will lead to increased flooding and affect the lives of millions of people around the globe. The study examines how the rise of sea levels affects the US real estate market overall, while narrowing it down to specific areas through the detailed analysis of the case studies of Miami and Tampa. If the sea level were to rise by 0.5 meters, Miami would become the city in the world with the largest value of assets exposed to flooding (Nicholls et al 2007). Therefore, it is important to better understand why this is the case and how this would affect its real estate market. Through the analysis of existing literature, which is the used method of collecting data throughout this study, it builds a clearer picture of how impactful the sea level rise could be for almost 40% of the US population by 2100 (Jones, 2019).

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List of Abbreviations

CDMP – Miami-Dade County's Comprehensive Development

EPA - Environmental Protection Agency

EU – European Union

FEMA – Federal Emergency Management Agency

FHFA – Federal Housing Finance Agency

GGE – Greenhouse Gas Emissions

GHG – Greenhouse gas

GSEs - Government-sponsored enterprises

NASA – National Aeronautics and Space Administration

NOAA – National Oceanic and Atmospheric Administration

OCC – Comptroller of the Currency

PLMBS – Private Label Mortgage Backed Securities

SEFRCCC – Southeast Florida Regional Climate Change Compact

SFHA - Special Flood Hazard Area

SFHDF - Standard Flood Hazard Determination Form

SWOT – Strengths, Weaknesses, Opportunities, and Threats

US/USA – United States of America

USACE – United States Army Corps of Engineers

1 Introduction

Many of today's most populated and influential cities in the world are located on the coast or nearby it. This is also the case for the United States of America (US/USA), for example, New York, Los Angeles, Boston, and Miami among others. These cities are centers of commercial and industrial activities and have historically played a key role in the US economy (Teicher, 2018). However, due to the changing climate, these are at an increased risk of flooding, caused by the likes of severe storms, increased intensity of precipitation, and the rise of the sea level. Organizations such as the UN's R!SE Alliance, have warned about the devastating outcomes the climate change will have on businesses and real estate around the world. Scientists have highlighted the US to be especially exposed, with North America currently having the highest total value of all exposed assets on the planet, while lacking flood defences compared to other exposed and high-income countries such as Japan, the United Kingdom., and the Netherlands (Hallegatte et al., 2013; Hanson et al., 2010).

To understand why coastal areas are becoming increasingly prone to flooding it is important to understand climate change and how this leads to a rise in the sea level. The sea level rises because solid forms of water located above sea level, such as ice and snow melt, running into the oceans increasing its total volumes and therefore, gradually causing the sea level to rise (Jiang et al., 2020). This is caused by global warming. But what causes global warming? According to Crowley (2002) we are still not 100% sure about all the exact causes of global warming, however, a widely scientific-backed theory, which will be explored in more detail throughout this paper, is that of the "Greenhouse Effect". The Earth's trace gas levels, also known as greenhouse gasses, are increased due to human activity (Hardy, 2003). These gases are furthermore capable of absorbing energy reflected by the Earth's surface, preventing them from re-entering space and consequently trapping them within the Earth's troposphere, heating up the Earth (Hardy, 2003).

While climate change, its causes, and its consequences are backed by an abundance of data, people's views and beliefs on climate change vary widely. Some people believe the data, while others think that climate change is overexaggerated, or even

a myth. Therefore, there are also many different attitudes towards it. This paper will try to identify if there are correlations between groups of people and their perceptions or if this is random, while also looking at how politicians and real estate industry leaders approach climate change, its consequences, as well as the perceived need for mitigation and adaptation. If the necessary mitigation and adaptation efforts are not implemented and high sea levels rise flood or inundates houses, communities, or even whole cities, this would have a devastating effect on the economy, the real estate market, and most importantly the people living in such areas. As of 2019, there are already 3.4 million US homes located in high-risk flood zones worth a total value of $1.75 trillion (Jones, 2019). If the sea level were to rise with a predicted worst-case scenario of 3.61 feet by 2100, 40% of the US population would be living in high-risk flood zones, yet still "political will to fight climate change is rather weak" and current goals and plans are not enough to keep temperatures at a safe level for humans (Jones, 2019; Skeiryte et al., 2022; Depledge et al., 2022) But why is that the case? The presence of the "Techno-Market Imaginary" could be one of the reasons for this, which is further explored in this paper.

What would happen if, we don't find a way to prevent the sea level from further rising and don't establish the needed flood prevention to protect the homes which will be affected by inundation or flooding? People could lose their homes and, in many cases, a majority of their wealth, but are the property owners the only risk bearers? In most cases, in the USA the risk of value loss of a home or a property is shared among multiple stakeholders. A property owner could have fully paid for their home and opted not to get insurance; in which case they do bear the full risk regarding their property. However, there are three other common constellations for owner-occupied homes in the USA, leaving the property owner with less risk, which will be further analysed in more detail.

Parts of the USA are or could soon be affected by flooding and the rise of the sea level. However, some areas are being affected harder than others. Data shows that the number of average annual floods on the east costs has increased significantly more, over the past 50 years, than on the west coast, where in some areas average flooding events are still occurring at the same rates (*Climate Change Indicators: Coastal*

Flooding, 2022). Florida is one of the states which has seen the biggest increase in flooding. Therefore, this study will analyse the cities of Tampa and Miami in detail to try to find the true implications which the sea level rise on these cities and what has or is being done to prevent flooding from happening. As it is aimed to find out how the rise of sea level affects the real estate market parameters, such as property values, demand, and changes in mortgage approval rates will be examined. This is to determine whether the flood risk and future inundation risks already impact the real estate market, as reflected by stakeholders' decision-making, or if such is unaffected.

1.1 Topic

"What are climate changes impacts, in particular the rise of sea level, on the US real estate market? The reason why analysing the real estate market and how it is affected by the sea level rise, is a good focus point for the study, is because, the real estate sector plays a key role in the US economy. In Florida one of the most exposed states to sea level rise, about 22% of its total GDP comes from real estate sector, creating a significant amount of taxes for the US Government (American Flood Coalition, 2020). At the same time however, real estate plays another vital role in the US society as this is where most people live and work. Therefore, analysing the how the real estate market will be affected, will simultaneously allow give a good implication how the socio-economic and political aspects of the US could be affected.

1.2 Research Questions

The following research questions allow farther analysis of the impact of the rise of sea level on the real estate market and what consequences this could bring for the US real estate market.

Research Question 1: What impact does climate change have on US real estate market?

Research Question 2: What are the consequences of global sea level rise on the real estate markets of coastal cities in the United States?

The research questions will be further supported and answered through the exploration of the following sub-questions

Sub-question 1: How will values of properties, which are affected by the consequences of sea level rise and hence at risk of flooding or inundation, be affected?

Sub-question 2: How does flooding risk affect the homeownership rate in coastal communities compared to the rental rate?

Sub Question 3: How does flood risk affect mortgage approval rates in high-risk flood areas compared to the rest of the USA?

Sub Question 4: What does the rise of the sea level mean for the demand demand for properties located in flood-exposed communities?

1.3 Aim

The aim of this thesis is to examine climate change and its impact on the US real estate market through the thesis question "What are climate changes impacts, in particular the rise of sea level, on the US real estate market?" In order to do so this thesis will look at what climate change is, its causes, and the consequences that it brings. Before analysing how climate change and the rise of the sea level affect the real estate market, the thesis intends to build a solid foundation of knowledge for the reader around the topic of climate change and the US real estate market. To do so topics such as people's views and attitudes, including that of the government, risk bearers, or the difference between mitigation and adaption will be explored. To determine the impacts of climate change on the US real estate market, a socio-economic approach will be applied, looking at both the financial implication sea level rise will have on the real estate market, as well as how this will impact the people living in such areas. Taking a closer look at cities of Miami and Tampa. The thesis will not only explore how

climate change impacts the US real estate market, but also how the US real estate market affects climate change, for example through the greenhouse gas emissions which the industry creates. With the completion of the research, it is the goal to outline the true impacts of climate change on the US real estate market by providing the answers to the research questions and being able to make educated predictions for coastal US real estate markets.

2 Literature Review:

2.1 Theory: The Greenhouse Effect

The probably most supported and believed theory about climate change is the theory of the "Greenhouse Effect". The following paragraphs will provide arguments, backed by scientific data on whether or not the "Greenhouse Effect" is a theory that correctly depicts the reasons for climate change.

2.2 What causes climate change

While it is still not 100% clear what the exact causes of climate change are (Crowley, 2000). Some researchers discuss the uncertainties of increases in solar irradiance others the lessening of volcanism effect on global warming (Crowley 2000) However, the most common explanation for global warming is the increase of anthropogenic greenhouse gases. Based on results and examinations of the past Crowley (2000), concludes that natural variability only has minor contributions towards the global warming of the 20th century and that the leading cause of global warming is the increase in global greenhouse gases, brought about by human society. Earth's climate has always been evolving gradually over time. However, over the past 200 years, the Earth's population has grown tremendously. According to Hardy (2003) in the early 2000s, 99% of all humans who had ever lived, were alive on the planet during that time. With such a population boom and the increased use of fossil fuels as a source of

energy, the atmosphere's carbon dioxide levels increased by 33% (Hardy, 2003). To see why carbon dioxide has such a significant impact on the climate, it is important to understand the science behind it and its function in the atmosphere.

The Earth's atmosphere consists of five layers: troposphere, stratosphere, mesosphere, thermosphere, and exosphere (Hardy, 2003). The troposphere, extending from the Earth's surface to roughly 11 kilometers in altitude, accommodates about 99% of the total atmospheric mass (Hardy, 2003). Within this layer, temperature decreases as altitudes increase. The next layer is the stratosphere, which extends between 15 to 50 kilometers of altitude, and accommodates about 1% of the mass of the atmosphere (Hardy, 2003). These two layers have the most influence on our environment, with the other three having only very minimal effect on the climate. There are three gases that makeup about 99.9% of the Earth's atmosphere (Hardy, 2003). Nitrogen is the largest component with about 78.09% followed by oxygen at 20.95%, and argon at 0.93% (Hardy, 2003). There can, however, also be found small quantities of other gases in the atmosphere also known as trace gases or referred to as greenhouse gases. These include carbon dioxide (CO2), carbon monoxide, nitrogen oxides, methane, chlorofluorocarbons, and ozone. While the quantities of these seem insignificant compared to the three primary gasses, the impact that these other gases have on the climate is far more significant (Hardy, 2003). This is because they affect the radiation balance, and thus affect the heat balance of the Earth (Hardy, 2003). The thermonuclear reactions occurring on the sun, produce solar radiation which furthermore encompasses energy (Hardy, 2003). This solar radiation travels through the atmosphere to the Earth's surface. On its journey, gases and particles absorb some of this energy. The electromagnetic spectrum has many different wavelengths such as short-wavelength X-rays, medium-wavelengths, which are visible light, and longer wavelengths which are infrared (Hardy, 2003). While ozone absorbs short-wavelength and middle-wavelength ultraviolet radiation, other gases such as carbon dioxide, methane, and atmospheric water vapor have very low absorption rates with the same wavelengths (Hardy, 2003). This allows visible light to pass through the stratosphere and light up the surface of the Earth. The gases water vapor, carbon dioxide, and methane have much higher absorption rates with

longer wavelengths (Hardy, 2003). As solar radiation reaches the Earth's surface, some of the energy is absorbed by the surface, while about 31% of the energy is reflected toward space (Hardy, 2003). This reflection is also called albedo. Different surfaces have different albedo. While the Earth's average albedo is at about 31%, forests, for example, only have an albedo of 5% to 15%, while snow has an albedo between 75% and 90% (Hardy, 2003). When radiation is reflected, a transformation of the wavelength occurs, increasing the energy's wavelength (Hardy, 2003). While carbon dioxide, water vapor, and methane were only able to absorb a little of the short and middle wavelengths, they are much more capable of absorbing the transformed long-wavelength energy reflected by the Earth's surface, thus preventing part of the energy from escaping into space (Hardy, 2003). About 83% of energy reflected and radiated from the Earth's surface is absorbed by the greenhouse gases and radiated back onto Earth. This way energy is captured within the troposphere and heats up the Earth (Hardy, 2003). Hence, the "Greenhouse Effect" got its name, as the windows from the greenhouse allow light energy to pass through however preventing heat from escaping and trapping the heat within. Today, greenhouse gases have a negative connotation with a lot of people, however, these gasses are essential to human life, as without the greenhouse effect the Earth's average surface temperature would not be 15 Celsius, but instead a staggering -20 Celsius (Hardy, 2003). As the amount of greenhouse gases increase, the amount of long-wave radiation being absorbed also increases (Hardy, 2003). This increases the back radiation and the heat trapped in the troposphere. Furthermore, surface types such as snow and ice, with great albedo, decrease, meaning more energy is absorbed by the Earth directly, allowing less energy to be reflected into space (Hardy, 2003). As seen, the increase in greenhouse gases has a snowball effect and therefore, has a significant effect on global warming and climate change (Hardy, 2003).

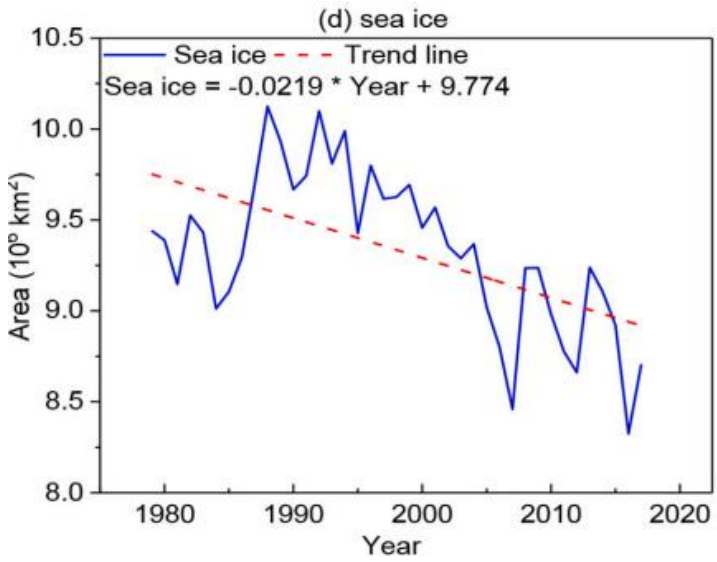
As no information was found to disprove the "Greenhouse Effect" theory, it can be concluded that this theory accurately depicts processes leading to global warming and climate change. With the information and knowledge available to date it can furthermore be argued that this is the main reason for climate change. However, it is important to state that many other natural and human activities, intensify this effect.

Human emissions of gases from human activities certainly amplify the effect and this additionally leads to other events, such as the melting of ice and snow, which then further enhances the "greenhouse effect". This is now explained in the form of a case study from Greenland.

2.3 A case study of Greenland's change in temperature and its consequences on sea level rise

A recent study conducted by Jiang et al, (2020) analysed the changes in temperature in Greenland throughout time, by examining previous studies and their findings with the most current data. Polar or Arctic Amplification refers to "the enhancement of near-surface air temperature change over the Arctic relative to lower latitudes" (Previdi et al., 2021) or in simpler terms "greater climate change near the pole compared to the rest of the hemisphere or globe" (Group, 2015). As Greenland is located in proximity to the North Pole, with three-quarters of the island being located within the arctic circle (Jiang et al., 2020), polar amplification means that Greenland will experience global warming and the increase in temperature to a greater extent than other areas of the world. With 82% (Jiang et al., 2020) of Greenland's surface covered with snow and ice, it plays a significant role in the global sea level rise. Not only does the melting of ice and snow allow for signification amounts of above-sea-level water to run into the ocean, but due to the sea ice albedo effect will further contribute to global warming (Jiang et al., 2020). The sea ice albedo effect increases the absorption of surface radiation and simultaneously allows for increasing volumes of water to evaporation contributing to an increase in atmospheric water (Praetorius et al., 2018; Graversen et al., 2008). Since 1980, the sea ice, as seen in Graph A, has decreased on average by a volume of 219,000 km2 per decade, reaching an all-time low, since the beginning of recordings, of 8,325,000 km2 in 2016 (Jiang et al., 2020). Between 1971 and 2017 the artic average annual temperature increased 2.4 times faster than the rest of the Northern Hemisphere (Jiang et al., 2020). Data shows that 2014-2018 were the five years that had the highest average annual temperate, indicating that the temperature increase is accelerating (Jiang et al., 2020). Between

1971 and 2017 the average annual temperature in the artic increased by a total of 2.7 Celsius (Jiang et al., 2020). Notably the temperature rose only by 1.8 Celsius during the warm seasons, comparably during the cold seasons it rose by 3.1 Celsius (Arctic Monitoring and Assessment Programme, 2019), affecting the production of sea ice. While the melting of the arctic sea ice would not cause a rise of the sea level, the melting of the ice sheets of Greenland would. According to data from National Aeronautics and Space Administration (NASA), if all ice sheets located in Greenland were to melt, this would give a rise to a sea level of up to 7 meters (NASA). With major cities all around the world, such as Miami, Mumbai, and Shanghai, located at sea level, this rise of sea level would have severe socioeconomic consequences worldwide (Nicholls et al., 2007).



Graph A: Sea Ice Volume

(Jiang et al., 2020)

2.4 People's perception of climate change

A climate change conference with the world's leaders in 2021 only had a scarce agenda of goals and concrete work plans. According to Depledge et al, (2022) these are not significant enough to make the necessary change to keep the temperature at

a level at which it is safe for humanity. It is up to the public and private society themselves to make the necessary contribution to climate change mitigation. Like Teicher (2018), Skeiryte et al, (2022) affirms that "political will to fight climate change is rather weak and the role of society is particularly important". Furthermore, political time frames are very different from those of climate risk adaptation, as politicians operate on a short-term basis, while adaptation implementation operates on a much longer-term basis (Molinaroli et al., 2019). It indicates that politicians might be less interested in pursuing climate mitigation and adaptation practices if their benefits of such are not seen within the politicians' short-term duty. This puts pressure on society to make a difference, with research suggesting that the public and private have the power to contribute to and influence climate mitigation (Stern, 2000; Jorgenson et al., 2019; Liobikiene and Poskus, 2019; Tsai et al., 2021). One way of doing so is by putting pressure on the policymakers, another way is for individuals to change their way of life to become more sustainable and climate-friendly. Both ways can make a difference and therefore, society's role in fighting climate change is of great importance (Skeiryte et al., 2022).

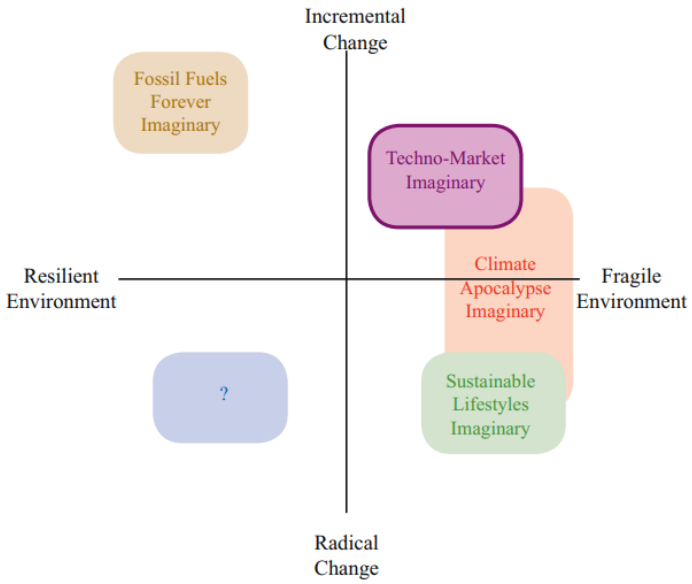
While we look at society's perception of climate change and its actions towards combating it, it should be questioned whether society can be counted as one or if people of different nationalities, beliefs, and ages should be assessed individually. Skeiryte et al, (2022) did just that, as they assessed different generations' behavior toward climate change. Multiple prior studies already stated that younger people more strongly believe in climate change (Hornsey et al., 2016) and that the European Unions (EU) older generations are less concerned about climate change than their younger counterparts. This, however, only seems to be the case for Europe, as studies by Knight and Hao (2022) and Gray et al. (2019) show that in the US there is an insignificant relationship between young and older respondents and their concerns about climate change. Furthermore, Ballew et al. (2019) explain that a larger portion of the Millennial generation understands that human activity is the reason behind climate change, compared to the older generations. The research which has been conducted on climate change perception among different generations is scarce, especially among EU countries (Skeiryte et al., 2022). While millennials do feel like

they are personally responsible for their carbon footprint (Gómez-Román et al., 2020), they are more likely to reduce their resource consumption, and recycle and reuse than generations X and Z (Lakatos et al., 2018). It is hard to tell which generations' behavior are the most climate-friendly, as studies have found climate-friendly behavior in all generations. People aged 34 years and older are more likely to behave in a more electricity-saving manner (Quaglione et al. 2017). Some studies supported this statement Bardazzi and Pazienza (2017), whilst other studies found there to be an insignificant relationship between energy-saving behavior and age (Nie et al. 2019). Older people are more likely to use their own cars (Böcker et al., 2016), on the other hand, studies have also shown that within the EU older people are more probable to use public means of transportation (Minelgaitė et al., 2020). Baby boomers are the generation most likely to choose not to use products that harm the environment compared to other generations (Squires, 2019). Every generation's contribution toward climate change mitigation is important, however since the next 30 years will be crucial regarding climate change, the younger generations play the most significant role out of all generations (Skeiryte et al., 2022). Therefore, it will become important that young people understand the risks of climate change and act upon such through a more climate-friendly behavior. While concern about climate change widely exist among younger people, more sustainable behavior is not a given. Jakucionyte-Skodiene and Liobikiene (2020), identified one of the barriers between climate change perception and climate-friendly behavior to be the cost that comes with climate-friendly behavior. This is furthermore backed up by research from Brügger et al. (2015). More wealthy people have the option to choose between regular products and the pricier or more expensive sustainable alternatives. However, less affluent individuals might not have the means to make such choices. As sustainable products often are more expensive to produce and thus cost more, less wealthy people cannot afford such products. One way of making sustainable behavior affordable for everyone would be through governmental intervention, for example by subsidizing sustainable products or imposing burdens on climate-harming products through additional tax. However as seen previously in this research, governments, and leaders state that the issue of climate change is "ripe for free market management" and additional studies show that many governments are not very proactive in fighting

climate change (Teicher, 2018). Especially in the US where there is very little intervention in the free market by the government, it is not to be expected that more sustainable alternatives will become available at more competitive price points unless the costs allow for such.

2.5 Techno Market Imaginary

There are many different understandings and beliefs about climate change. Levy and Spicer (2013) state that numerous people still believe that climate change is a myth or overexaggerated, while others understand the risks and consequences, but trust in future innovations to overcome the problem. “Imaginaries” represent such different viewpoints and “provide a shared sense of meaning, coherence, and orientation around highly complex issues” (Taylor 2004). Levy and Spicer took Jessop’s (2010) Gramscian comprehension of imaginaries and applied it to the sphere of climate change. By doing such they identified and further analysed the four core climate imaginaries: “fossil fuels forever”, “climate apocalypse”, “techno-market”, and “sustainable lifestyle” (Levy & Spicer, 2013). In the “fossil fuels forever” scenario the imaginary believes that there is plenty of fossil fuel available, which with the right technology can be extracted, and that there is little to no scientific agreement toward the fossil fuels’ impact on the climate. The “climate apocalypse” imaginary believes that in the future climate change bring forth severe conditions making the world nearly inability for society. The “techno-market” imaginary believes that the free market will invent technological solutions to combat the problems of climate change. The fourth imaginary, which Is the “sustainable lifestyle” imaginary believes in society changing its habits to become more sustainable and thus allowing the economic system to operate without negatively impacting the climate. The standpoint of the imaginaries toward environment and change can be seen on the position Graph B below. Levy and Spicer argue that the different “climate imaginaries” are a key issue in addressing the problem of climate change and hence hinder responses. This also leads to a lack of integration of science disclosing the potentially catastrophic consequences of climate change into the economic practices of today.



Graph B: Climate Imaginaries

(Levy & Spicer, 2013)

Teicher, (2018) examines the "techno-market imaginary" at a more in-depth level and furthermore analyses its role within the real estate sector (Teicher, 2018). She describes the "techno market imaginary" as "optimism that organizations can adequately address environmental problems through technological and market solutions, becoming more competitive as a result" (Teicher, 2018). Additionally, "techno-market imaginaries" also tend to see the opportunity side of risks rather than just the negatives. For example, firms that acknowledge the financial risks of flooding+ went on to turn their flood risk responses into a competitive advantage, thus creating a business22esearch22nity for themselves. Teicher's studies disagree with Levy and Spicer's (2013) statement that since 2009, the techno-market imaginary has been at an impasse in national politics. She argues that the techno-market imaginary is still present and active in many regional and local contexts. Statements such as "Urban fire was the climate change of its time … within 50 years, urban morphology was transformed because capital demanded i"" (Douglas, 2015), support this argument. With real estate industry leaders conveying climate change as being "ripe for free market management" (Teicher, 2018), it is clear to see that the belief of the "techno-

market imaginary" is still widely shared among leaders and within the real estate sector, despite reports warning of the severe risks of climate change and the call to immediate action (Bloomberg et al., 2014; UNISDR, 2015). Teicher claims that the climate risk is merely addressed by real estate firms unless these risks become financial risks. Therefore, are climate risks also assessed in financial terms.

Teicher (2013) identifies four factors, which influence real estate firms' decisions making to consider the climate risk of flooding as a financial risk and, hence raising its importance. The first is the increase in flood insurance costs for flood-exposed properties. The second factor is that of directly experiencing flooding. Firms experience financial losses with their properties losing operational capabilities over a period of time, consequently driving responses to be taken. This is an especially powerful influence on decision-making, which is also backed by numerous studies on flood risk (Birkholz et al., 2014; Kellens et al., 2013; Lujala et al., 2014). Another factor is that of proxy experience. This form of experience is not gained directly by the firm, but instead by other firms or property owners within proximity. The fourth factor identified that influence of decision-making comes from consultant input.

The23esearchch shows that in the US a common attitude towards climate risks is to let the free market manage its response. Those firms only respond to climate risks once they become financial risks. This, not only, puts the focus on the economic implications, rather than the social and environmental ones, but it also generates responses and solutions to satisfy the economic aspect, while potentially neglecting the social and environmental aspects.

While these studies show that there are many different approaches toward climate risks, and some groups of people manage to turn the risks into opportunities, they still let numerous questions arise, such as "How should society collaboratively work towards goals based on beliefs which are not shared by all parties and not strictly enforced by the authority". This leads to further questions such as "Is there a lack of available education on climate change". Based on research conducted for this study, there are aspects of climate change and its consequences towards more niche areas that lack scientific research, however, climate change as an overall is one of the most

researched topics hence a wealth of information is available to the public (Skeiryte et al, 2022). Therefore, it should be analysed "Why, over the course of several decades, climate change mitigation has not been sufficiently implemented".

2.6 Mitigation vs Adaptation

Biesbroek et al. (2009) describe mitigation as the contribution towards a global goal to slow down the negative environmental trends, also referred to as the negative effects of climate change. While adaptation is focused on increasing the resilience of a city or area toward the harmful impacts caused by the environmental changes. Taking greenhouse gas (GHG) emissions on an urban level, mitigation focuses on decreasing the total GHG emissions created by the city, through transportation, waste, industry, infrastructure, and land use. Adaptation, on the other hand, focuses on modifying the city to better withstand the negative impacts of climate change (Hritonenko & Yatsenko, 2022). In simple terms, mitigation aims to prevent certain events from occurring, while adaptation aims to minimize the negative implications that such events have. Mitigation and adaptation do not always go hand in hand and conflicts of interest arise.

Some researchers have argued that because of the differences in various aspects, mitigation and adaptation policies should be implemented separately (Tol, 2005). While other researchers believe that mitigation and adaptation policies should be integrated with one another throughout all governance levels stretching from the local level to a global level (Hunt and Watkiss 2011; Brechet et al. 2013; Brechet et al. 2016; N. Hritonenko et al. 2020; Landauer et al., 2019). This furthermore shows the lack of unity among experts in tackling the challenges of climate change. Lindberg and Grimmond (2011) present the conflict of mitigation and adaptation, as in hot regions of the increased use of conventional air-conditioners helps cities adapt to increasing temperatures, however at the same time increases the city's greenhouse gas emissions, which counteracts the mitigation efforts of decreasing the greenhouse gas emissions. Other instances, such as cities recommending builders to add additional green and vegetated areas to their buildings, also known as urban greening, have

shown that green exteriors help slow surface runoff, thus decreasing the load on the sewer systems during heavy rainfall and serving as a natural protection against heat. This furthermore decreases the usage of air-conditioning (Tremeac et al., 2012). This example shows the positive execution of adaption strategies, while also contributing to the mitigation goals of reducing greenhouse gas emissions. Therefore, it should be questioned, not whether the interests of mitigation and adaptation can be integrated among different levels of governance, but instead if adequate research into possible solutions satisfying both the goals of mitigation and adaption has been conducted, to draw conclusions on the discussion on whether the two should be integrated or not.

2.7 Who bearers the risks posed by climate change

A study by Woodwell et al (2022) identified two different types of direct risks that real estate market participants could face as a result of climate change. Physical and transition risks. Furthermore, counterparty risks and operational risks are added to the framework and used in the study to assess who owns the climate risk associated with a property. The Financial Stability Board's Task Force on Climate-related Financial Disclosures defines physical and transition risks in a report as follows: "Physical risks resulting from climate change can be event-driven (acute) or longer-term shifts (chronic) in climate patterns. Physical risks may have financial implications for organizations, such as direct damage to assets and indirect impacts from supply chain disruption. Organizations' financial performance may also be affected by changes in water availability, sourcing, and quality; food security; and extreme temperature changes affecting organizations' premises, operations, supply chain, transport needs, and employee safety" (Task Force on Climate-related Financial Disclosures, 2017). In more simple terms, physical risks can cause materialistic damage to the property causing its value to decline, while transition risks are changes in the operation of the property, such as increased tax rates and insurance costs among others. Counterparty risk refers to the reliance on another party and the possibility of them not being able to fulfil their part of an agreement. For example, if a lender has high counterparty risk as they rely on the property owner to repay their mortgage. Operational risk

resembles the possibility of operations of property not performing as intended. While physical and transition risks incorporate a broad array of direct real estate affecting climate risks, other frameworks have been established to analyse the more specific direct as well as indirect risks associated with climate change and the real estate market. The Federal Housing Finance Agency (FHFA) risk framework includes credit, operational, market, business, and liquidity risks (12 CFR § 1239.11–- Risk Management., n.d.) Another framework presented by the Office of the Comptroller of the Currency (OCC) includes the same risks apart from not including the business risks, however adding legal/compliance risks as well as other non-financial risks (Office of the Comptroller of the Currency, 2021). A risk category included in both the frameworks of FHFA and OCC, as well as in the study by Woodwell et al. (2022), is operational risk. This shows that there is not one agreed-upon procedure for assessing the risks posed by climate change, but instead numerous individual approaches in doing so.

There are four major stakeholders in the US real estate market that bear the majority of financial risk. These are the property owner, the insurance provider, the portfolio lender/mortgage servicer, and the Government-sponsored enterprises (GSEs), FHA, or Private Labels MBS, which we will refer to as the mortgage investor. In 2021 there were approximately 80 million owner-occupied homes in the US. Out of these 80 million owner-occupied homes, approximately 30 million are fully paid off, and therefore, do not have a mortgage on them. Furthermore, out of those 30 million homes, some have insurance others do not (Woodwell et al., 2022). This exact figure was not identified in the research.

For those who own homes without insurance, shown as A.1. (Woodwell et al., 2022) on Graph C the sole risk bearer is the property owner. They take on full risk for both the physical and transitional risks presented by climate change. The only risk relief that they can receive, which is not guaranteed, is governmental support.

Displayed as A.2. in Graph C(Woodwell et al., 2022) are property owners with insurance. In exchange for premium payments, the property owner passes on the majority of the physical risk to the insurance provider. The insurance provider now

holds the physical risk as well as a small proportion of the transition risk. However, the majority of the transition risk still lies with the property owner, as the insurance provider can change the premiums or deductibles according to the conditions. Since most insurance agreements contain deductibles, the property owner still owns some of the physical risks. As the property owner now relies on the insurance provider to fulfil their responsibilities in case of damage caused to the property, they take on a certain degree of counterparty risk towards the insurance provider. This is the risk of the insurance provider deciding not to carry out their service or not being capable of doing such.

About 48 million owner-occupied homes have a mortgage loan on the property (Woodwell et al., 2022). These properties share the risk between additional parties such now portfolio lenders or mortgage servicers and mortgage investors, as have active stakes in the property.

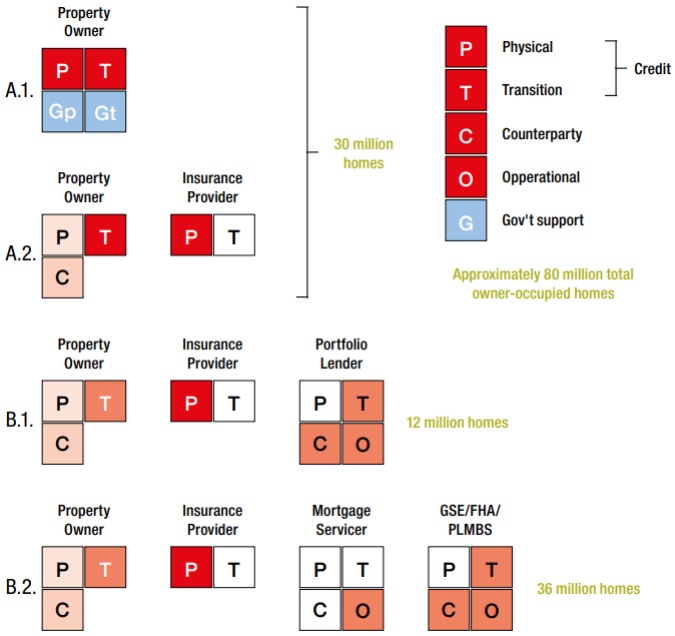
About 12 million of the 48 million homes with mortgages have loans from portfolio lenders (Woodwell et al., 2022). Instead of selling the mortgages to investors, they are kept in the lender's portfolios, usually by banks credit unions, and other lenders. In this constellation, shown as B.1. (Woodwell et al., 2022) physical and counterparty risk apply for both the property owner as well as the insurance provider. The transitional risk for the insurance providers remains the same. The transition risk is shared between the property owner and the lender, as the lender holds an interest in the property. The portfolio lender does not take on any physical risk. Counterparty risk is also taken on by the lender, through the physical risk borne by the property owner, and the physical risk carried by the insurance provider. The counterparty risk of the lender is larger than that of the property owner as they rely on two parties fulfilling their responsibilities. The lender also takes on a risk, not encountered by the property owner and insurance provider, which is operational risk. As the lender's operations could be disrupted and operations with the insurance provider and property owner does not work as intended.

The more common mortgage constellation, B.2. (Woodwell et al., 2022), with about 36 million owner-occupied homes is that with a mortgage servicer and investors.

Compared to portfolio lenders who keep ownership of their mortgages, with this constellation, banks and other lenders who issue the loans, sell these to Government-sponsored enterprises (GSEs); such as Fannie Mae or Freddie Mac, FHA/Ginnie Mae or private label securitisers, which hold and furthermore sell these to investors (28abelled as GSE/FHA/PLMBS on the Graph C). When securitising mortgages, individual mortgages are pooled together in bundles to further be sold on to investors in return for cash.

To better understand: "The GSEs' core function is to ''securitize'' mortgages. The GSEs buy mortgages from originators, ''package'' them into mortgage securities that are sold in the capital markets and send funds back to the originator" (Olson, 2010). Compared to mortgage lenders like banks and other lenders, GSEs such as Fannie Mae and Freddie Mac, do not directly lend money to the public (Segal, 2020). Research shows that most people who hold have taken mortgages, know what mortgage servicer they pay their mortgage to, but ultimately do not know who owns their mortgage (Olson, 2010).

The risks for the property owner and insurance provider and insurance provider stay the same whether the mortgage is sold to an investor or held by a portfolio lender. The mortgage servicer, just like the portfolio lender does not take on any physical risk, however, it also passes on the transition risk as well as counterparty risk to the investor who now owns the mortgage. The only risk left to the mortgage servicer is the operational risk as they are operating with each party. The mortgage investor, as the owner of the mortgage loan, takes on the same risks as the portfolio lender. These include the transition risk, the counterparty risk, and the operational risk.

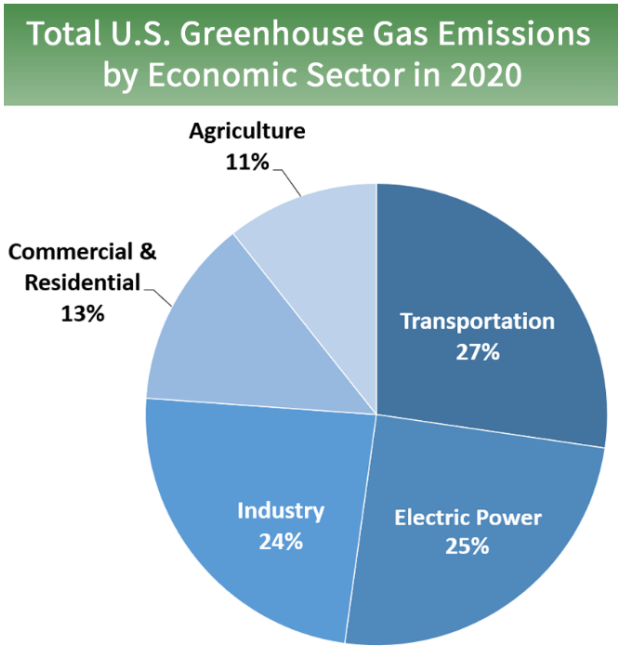


Graph C: Risk bearers of owner-occupied homes

(Woodwell et al., 2022

2.8 The US real estate sector's greenhouse gas emissions

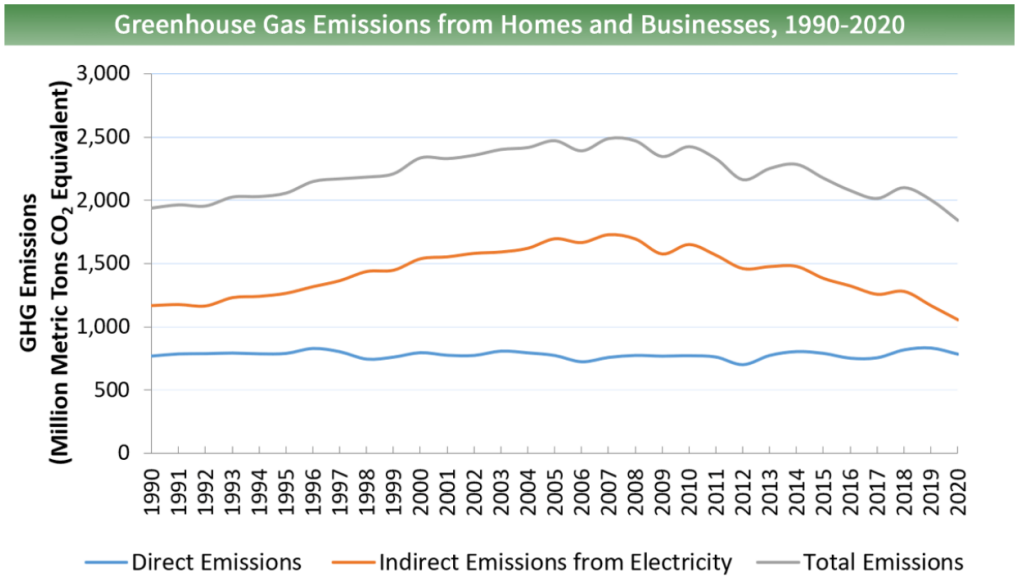
A news article by Concrete Products provides data relating to the carbon emissions produced by the real estate sector. Data gathered on real estate companies and funds show that such have been able to reduce energy consumption by 1.2%, water usage by 1%, and the produced greenhouse gas emissions (GGE) by 2%, along with improvements across all categories of the ESG, Environmental, Social, and Governance, performance metrics. Additionally, studies have shown that real estate companies' interests have shifted more toward their occupant's well-being and health (Concrete Products, 2016). As shown in Graph D, since a high of GGE around 2007 the combined emissions produced, both direct and indirect, from homes and businesses, have had a decreasing trend, decreasing by 5% from what they were in 1990. This indicates that the real estate sector, which is one of the most polluting industries in the world, is taking the right steps toward becoming more sustainable and efficient.



Graph D: Total U.S. Greenhouse Gas Emissions by Economic Sector in 2020 (Sources of Greenhouse Gas Emissions, 2022)

On the other hand, Chief of Strategy Andy Darrell from the Environmental Defense Fund stated, “The world’s buildings account for about 40 % of all energy use and in major cities like New York and London, that figure doubles. What’s more, up to half of this energy is wasted” (Concrete Products, 2016). According to the United States Environmental Protection Agency, EPA, in 2020 Commercial and Residential real estate was the fourth biggest producer of greenhouse gas emissions in the US, with 13% of the total GGE. This is more than the agriculture sector, which only accounted for 11%. However, electricity production produced 25% of the US total GGE, coming in second place only behind transportation with 27% (Sources of Greenhouse Gas Emissions, 2022). Referring to Graph E, it is notable that the majority of greenhouse gas emissions from homes and businesses are indirectly produced through electricity consumption. The difference between direct and indirect emissions has become less drastic from its peak variance in 2007, and the indirect GGE from electricity has seen a decreasing trend, at the same time as the total direct GGE has been stagnant (Sources of Greenhouse Gas Emissions, 2022). However, taking Andy Darrell’s statement into consideration, that up to half of the energy in real estate is wasted,

the question arises, why so much energy is being wasted and how much less GGE would be produced by the real estate sector if the energy wasted was reduced. To answer this question, research into the total amount of wasted energy over time would need to be conducted, to be able to clarify whether there is a correlation between the decreasing indirect GGE from electricity and the percentage of wasted energy, or if there is no correlation and percentage of wasted energy has stayed the same or even increased.



Graph E: Greenhouse Gas Emissions from Homes and Business, 1990-2020

(Sources of Greenhouse Gas Emissions, 2022)

2.9 Who is affected by the rising sea level

Over history coastal areas have always been popular locations for humans to settle. In current times this is still the case. While only 10 percent of the US counties are located along the coast make up for 45 percent of the US GDP, employing 37 percent of the US workforce (Kildow et al., 2014) and allowing 39 percent of the US population to call these counties their home (NOAA, 2013). Some of the US's most important metropolitan areas are located on the coast and thus are vulnerable to flooding caused by the rise of the sea level. These include New York, San Francisco, and Miami.

Looking more globally it is clear to see that many of the most populated and economically important cities are located coastally. According to Pelling and Blackburn (2014) as of 2011, there were a total of 23 megacities in the world. Data on megacities varies between studies and publishers. Megacities typically are described as urban areas/agglomerations with a population of over 10 million people. Some studies included cities with populations above 8 million while using other parameters to assess the population. Other studies highlighted that the numbers were estimates for many cities, considering the unregistered population. Out of these 23 megacities, 16 are coastal, with Tokyo, the largest city in the world, being one of them (Pelling & Blackburn, 2014). This list furthermore includes global trading hubs such as Shanghai, Osaka-Kobe, and Shenzhen, as well as a long list of capital cities such as Buenos Aires, Manila, Jakarta, and more. In 2011 these coastal megacities had a combined total population of around 242 million, making up about 3.5 percent of the global population (Pelling & Blackburn, 2014). Two-thirds of all cities with a population above 5 million are partially located within 10 meters elevation above sea level. The trend of people moving from rural areas to urban areas, also known as urbanization, is not expected to stop. In the year 2000, urban areas accounted for 3.1 percent of the US total land mass, with research suggesting it will reach 8.1 percent by the year 2050 (Nowak & Walton, 2005). While the urban area might not be directly correlated to the urban population or a city's total real estate values, it converts vegetate land into impervious areas. Roads, rooftops, or other structures build from concrete or asphalt do not allow water to infiltrate into the surface. Therefore, the majority of precipitation will run off and hence increase the risk of flooding if adequate drainage systems are not established (Pallathadka et al., 2022). Pluvial flooding, which is when the volume of precipitation surpasses the drainage system's drainage capacity, can occur as a result of such (Rosenzweig et al., 2018). According to it Cutter et al. (2018) during heavy rain and storms, impervious surfaces found in abundance in the urban setting are the primary cause of urban flooding. Urban sprawl, the rapid outward expansion of cities, is making it difficult to combat this problem.

This study examines cities, its population, and real estate, however, other studies have found that communities of minorities are proportionally more exposed to the

consequences of natural disasters and flooding (Fothergill & Peek, 2004, Zahran et al., 2008). Correlations between communities' ethnic groups and disaster mitigation, as well as more green infrastructure (Eisenman et al., 2007, Dai, 2011, Nesbitt et al., 2019). Furthermore, Martinich et al., (2013) state that socially more vulnerable areas will be more exposed to sea level rise since they are less likely to be protected and hence more likely to be abandoned in the future. Pallathadka et al., (2022) assesses such inequalities in depth in the cities of Atlanta, Phoenix, and Portland, which are all non-coastal cities and therefore, less relevant for this study.

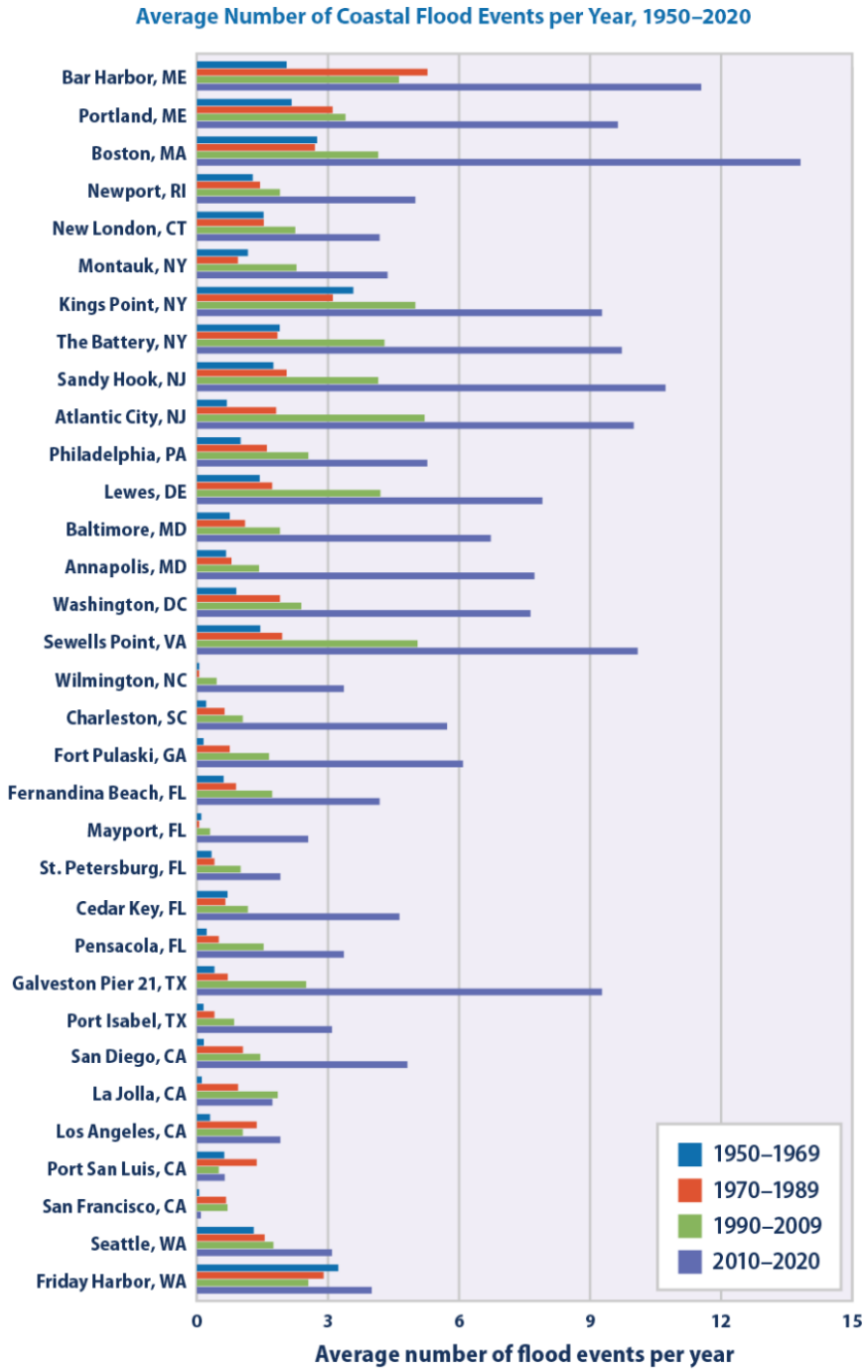
Many coastal US communities are already experiencing climate risks with annual flood events increasing drastically. As can be seen on Graph F, which displays the average number of flood events per year, based on data provided by the National Oceanic and Atmospheric Administration (NOAA). It can be seen that many cities which were not experiencing flood events between 1950 and 1969 now encounter close to three flood events per year. At the same time, cities that were already prone to flood events between 1950 and 1969, have seen the annual average of flood events increase considerably. For example, the cities of Portland and Bar Harbor in Maine were already facing around 3 flood events over the second half of the 20th century, Since 2010 these flood events occur around 10 to 12 times on a yearly basis.

What stands out from the data is the rapid increase in yearly flood events over the past three decades shown as the green and purple bars on Graph F and the difference between the East and West Coast. Many cities, especially those in the states of New Jersey and New York, saw a big increase in flooding events between 1990 and 2009. More dominant, however, is the increase in recorded flood events between 2010 and 2020. Almost every city's yearly flood events displayed on Graph F have doubled in the last 10 years, with some cities even experiencing three times the flooding events they did between 1990 and 2009. Boston, one of the largest and most influential cities on the list, is leading the way with about 14 flood events a year, up from around four before 2010. Another city that has seen a major increase in flood events is Galveston, Texas. From having on average less than one flood event a year, they are now faced with an average of more than nine each year. Standing out are the cities located in Florida and along the South-East Coast. Even though they are not experiencing as

many floods as compared to the more northern cities on the East Coast, the difference from 1950-1969 to 2010-2020 is immense. Pensacola, Cedar Key, and Fernandina Beach were used to all record less than 1 flood event a year, however, in 2020 this number increased to around 4.

To be highlighted is also the difference in the evolution of yearly flooding events between the US East Coast and West Coast. While the East Coast has seen a drastic increase, most cities on West Coast have seen a much more moderate increase with some cities even recording a decrease in flood events. Los Angeles is still recording around one to two floods a year, and San Francisco is experiencing less than one flood event a year, with only San Diego seeing a strong increase in flood events.

This raises the question of why the East Coast is more prone to coastal flood events than the West Coast and why the East Coast is experiencing such a strong increase in flood events.



Data source: NOAA (National Oceanic and Atmospheric Administration). 2021. Tides and currents: CO-OPS derived product API. https://api.tidesandcurrents.noaa.gov/dpapi/prod.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Graph F: Average Number of Coastal Flood Events per Year, 1950-2020

(*Climate Change Indicators: Coastal Flooding*, 2022)

2.10 US Case Studies

With a sea level rise in a moderate scenario of around 67 centimeters by 2100, close to 6,000 square miles of US land area could be at risk of inundation (Martinich et al., 2012). According to Martinich et al. (2011), it is very likely that parts of this land will not be protected and simply be abandoned. This also includes populated areas and communities. In 2011, calculations predicted that 1,630,000 people would be directly affected by the rise of sea level, however, based on more up-to-date studies and the growth of coastal communities it is to be expected that this number will keep growing (Martinich et al., 2012). The population at risk and protection levels also vary between the different regions, the more affluent North Atlantic coast, will see the majority of the population be protected against the rise of sea level 1. The Gulf Coast on the other hand is less likely to see adaptation responses to protect the population and more likely to simply abandon areas (Martinich et al., 2012). What is stands out is also the difference in protection between the different vulnerability groups within the population. For example, only 8% of the least socially vulnerable living in inundation-risk areas of the Gulf Coast are improbable to be protected against sea level rise (Martinich et al., 2012). From medium to high socially vulnerable people, most people are not to expected to benefit from adaptation efforts, with even more drastic numbers for the most socially vulnerable among the population at risk. 99% of such areas in the Gulf Coast are expected to not be protected at all and therefore, needed to be abandoned (Martinich et al., 2012). With high social vulnerability, being strongly related to poverty and areas of poverty are heavily correlated with ethnic backgrounds, it is clear to see who will be most affected by the rise of sea level (Iceland, 2019). This shows that there is little to no interest on the Gulf Coast to protect people who are most in need of protection. It should be further analysed as to why this is the case. Is it financially the least feasible, socio-economically the least beneficial, or what are the true reasons for such decisions?

2.10.1 Case Study Tampa Bay Area

In a study conducted by Fu et al., in 2016 financial risks of us coastal regions posed by climate change and sea level rise are analysed. The Tampa Bay area is used as a case study for which more in-depth research was performed and detailed results shared. Florida has throughout history proved itself to be very vulnerable to many severe storms, furthermore due to its low elevation and long shorelines it is also very vulnerable to the rising sea level. With the beaches and warm weather being one of the main attractors of people to Florida, many of its most populated areas, including large cities such as Miami, Fort Lauderdale, and Tampa, are located along the state's long shorelines. This has led to Florida having the third biggest population density among coastal counties in all the US (NOAA, 2013). 70% of coastal properties in Florida are residential (FOCC, 2008). This means that not only could the rise of sea level cause major economic damage, but also lead to large displacement among the Floridian population. The Tampa-Saint Petersburg metropolitan area is home to around 2.9 million people according to Nicholls et al., (2008) is among the ten cities in the USA with the highest value of assets exposed to coastal hazards. The study by Fu et al., (2016) 1 collects property value data from Pinellas and Hillsborough County which make up incorporate most of the Tampa-Saint Petersburg metropolitan. While waterfront properties are directly exposed to the water, numerous studies show that there is a positive correlation between property values and the proximity to the coasts (Bin et al., 2011; Gopalakrishnan et al., 2011; Jin et al., 2015). The further from the coast, the lower the average value of the property. Within 5000 feet of the coastline, there are 188,241 residential properties in Pinellas County and 131,266 residential properties in Hillsborough County (Fu et al., 2016). The 319,507 residential properties have a combined value of 72.2 billion US dollars (Fu et al., 2016). Losses in Hillsborough County could range from $129 million if the seal level rises by 1 foot, to a potential loss of $4,121 million if the sea level rises by 6 feet (Fu et al., 2016). This would be a loss of around 14.4% of the total value of properties in Hillsborough County located within 5000 feet of the coastline. In Pinellas County, on the other hand, 1 foot of sea level rise would cause a loss of $20 million (Fu et al., 2016). This is only 0.05% of the 2015 value whereas for Hillsborough County sea level rise of 1 foot would already cause a loss worth 0.45% of the 2015 value (Fu et al., 2016). However, the

study shows that Pinellas County will experience a much larger increase in potential losses with each foot of sea level rise. If the sea level were to rise by 6 feet by 2050 Pinellas County would see a loss worth a staggering $7,152 million, 16.41% of the total value of properties (Fu et al., 2016). Fu et al., (2016) calculated the inundation value of losses by 2050, the losses caused by areas of land being permanently flooded, for each foot of sea level rise from 1 foot to 6 feet using both the spatial lag regression model and the spatial error regression model. Those results are furthermore presented with a 3% discount rate and without as seen in Table A (Fu et al., 2016). What stands out is Pinellas County's low exposure to low sea level rise and high exposure to high sea level rise, while Hillsborough County's potential costs more gradually increase with each additional foot of sea level rise. Pinellas County would only experience a low loss of value loss from 1 and 2 feet of sea level rise, however, once the sea level rise exceeds 3 feet the costs increase by 10 times. This indicates that a large portion of the residential properties in Pinellas County sits at around 3 feet above sea level. Hillsborough County on the other hand does not have a certain elevation level that stands out. It is highly opinion based on whether adaptation measures should be implemented and furthermore whether such should be done by the government or the private sector. However, if Pinellas County should step it, it is highly advised that such should be done before the sea level rises by 3 feet from the current sea level.

Inundation loss due to sea level rise.

Jurisdiction	Model type	Total inundation losses in 2050 W/O discounting						Total inundation losses in 2050 with 3% discounting					
		1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft
Hillsborough county	Spatial error	129.31	164.33	287.65	752.45	1947.34	3858.96	45.95	58.40	102.23	267.41	692.05	1371.41
	Spatial lag	130.89	166.32	301.34	791.91	2058.63	4121.74	46.52	59.11	107.09	281.43	731.60	1464.80
Pinellas county	Spatial error	19.77	73.22	754.15	2118.52	4045.45	5927.65	7.03	26.02	268.01	752.89	1437.69	2106.59
	Spatial lag	23.14	88.64	912.10	2544.58	4855.99	7151.77	8.22	31.50	324.15	904.30	1725.74	2541.62

Note: ft stands for foot (feet); all losses are in (2015) million dollars ($).

Table A: Inundation Loss due to Sea Level Rise

(Fu et al., 2016)

2.10.2 Case Study Miami

In 2019, Molinarolli et al., studied the adaptions implemented to combat the rise of sea level in Miami, Florida, USA, and Venice, Italy. Even though there is comprehensive information on both cities, this paper will be focused more heavily on Miami, as this study analyses the impacts of climate change on the US real estate market. The lack of clarification about the scale of Miami for certain data, creates some uncertainty, however due to the regular inclusions of other municipalities within the Miami-Dade County and talks about the everglades, it can be assumed that when no scale is added, the Miami metro area is addressed. Miami, also known as the "Cruise Capital of the World", and "Wall Street of the South" among others, is a significantly important US city, with a metropolitan population of over 2.6 million people (Molinaroli et al., 2019). It not only attracts tourists, by being a tourist hotspot but also attracts residents looking to call Southeast Florida their home. In 2021 the Miami-Fort Lauderdale-Pompano Beach metro area had a population of 6.1 million people (Statista, 2022). People and companies continue moving to Miami even with its great exposure to rising sea levels, and extreme weather events, such as hurricanes and tropical storms, occurring frequently (Molinaroli et al., 2019). Although the rising sea level is becoming an increasing concern for Miami, especially due to the fact that 90% of the city is less than 6 meters above sea level, it is not a new problem (Molinaroli et al., 2019). Since the 1930s South Florida has already experienced a rise of the sea level by roughly 20 centimeters (Zervas, 2009). The rise of the sea level is greater in South Florida compared to what other US coastal areas are encountering (Valle-Levinson et al., 2017) and is also above the global average of sea level rise (Molinaroli et al., 2019). This is also felt by the city through the increase in flooding. Extreme tides now flood part of the western end of Miami Beach about 6 times a year, during fall (Molinaroli et al., 2019). This flooding is predicted to become a very frequent occurrence and people living in Miami Beach will have to expect their streets to be flooded on a daily basis if no flood prevention plans are implemented. According to predictions made by the Union of Concerned Scientists (2017), by 2045 the streets of Miami Beach will be subject to flooding around 380 times every year.

In 1948 early actions were taken to reduce the risk of flooding. This included the construction of several canals and levees redirecting and altercating the flow of freshwater to help prevent flooding (Grunwald 2007). As a result, the freshwater sheet flow to the Everglades National Park and furthermore Florida Bay was reduced (Sklar et al. 2005; Aumen et al. 2015). Sheet flow to Biscayne Bay, the Bay around which large parts of Miami are located, is also being controlled through the construction of various drainage canals which can be opened and closed according to need (Molinaroli et al., 2019). While this has claimed a substantial area of land now suitable for residential development, allowing Miami to further expand toward the West, it has also negatively affected parts of the ecosystem, increasing the saline levels of the Biscayne Bay and thus dispossessing it of some of its estuarine functions (Lodge 2010). Additionally, studies have found parts of Miami to be experiencing land subsidence, meaning the gradual sinking of areas of land due to changes in underground material movement, including the removal of water, however, can also be caused by several other factors such as soil compaction or soil erosion (Fiaschi and Wdonski, 2016; NOAA., n.d.)

This is happening at a rate of around 3mm per year, and while this might not seem like a lot, however, added up to around 16 to 24 cm since the city was first built, with 25 percent of Miami-Dade County land being less than 1 meter above sea level, it's clear to see why this is a problem (Fiaschi and Wdonski, 2016; Molinaroli et al., 2019). The combination of the land subsidence and the rise of sea level has led to additional areas of Miami being highly exposed to flooding (Bloetscher and Romah 2015). Florida also experiences extreme weather conditions, including hurricanes and heavy rainfall which pose a risk of flooding. According to calculations from Pile et al. (2008), from all hurricanes which affected the USA between 1900 and 2005, 9 of the 20 hurricanes which caused the highest normalized damages were in Florida. Combined with the rising sea level, its population, and rapid development of real estate this makes Florida one the most exposed areas in the world, based on potential financial damages. If the sea level were to rise by 0.5 meters by 2070, Miami would have the most exposed assets of any city in the world based on projected developments and inhabit the world's 9th largest population exposed to coastal flooding (Nicholls et al 2007). If no

adaptation procedures are implemented and the sea does rise by 0.5 meters by 2070 around 300,000 people could be displaced (Hanson et al. 2011; Hauer et al. 2016, Treuer et al. 2018). These numbers do not include the neighboring counties of Broward and Palm Beach, which are home to millions of people and also exposed to flooding. If the sea level rises as predicted, Florida could experience flood losses of around $25 billion yearly by 2050 (Sweet et al. 2017; Treuer et al. 2018). With continued population growth, expected sea level rise and the planned adaptation measures being realized, by 2050 Miami itself could encounter up to $2.55 billion in losses from flooding (Hallengatte et al. 2013; Kulp and Strauss 2017).

In 2013, under President Barack Obama, the President's Climate Action plan was released, which was aimed at strengthening the federal and local levels to identify the risks posed by climate change and furthermore make the needed changes (Molinaroli et al., 2019). Through the distribution of federal grants, communities' adaptation efforts should be assisted to help US communities prepare for potential difficulties they might experience through climate change (Molinaroli et al., 2019). In January 2017, as Donald Trump took over as the 45th president of the United States, many such climate change plans were shortly abandoned, despite US reports voicing the utter need for climate change adaptation (Fleming et al. 2018). The most important federal programs in the fight against climate change, include the Federal Emergency Management Agency's National Flood Insurance Program, as well as the US Army Corps of Engineers (USACE). The USACE also works together with the South Florida Water Management District, on a three-decade-long restoration plan of the Everglades, worth over $10 billion (Aumen et al. 2015). Furthermore, federal agencies are providing local governments with data and tools to assist with their adaptation work (Molinaroli et al., 2019). Molinaroli et al., 2019 study presents all major adaptation efforts in both Miami and Venice as well as highlights each effort's pros and cons.

Miami			
Realized	Pros	Cons	Transferability
selecting the engineering and other relevant expertize needed" to develop plans for flood protection, salinity barriers, pumps, and road/bridge designs.			
2016: the City of Miami Beach adopted new standards for major renovation and new construction that will provide for increased protection against storm surges and sea level rise.	Protection against sea level rise and storm surges	Not required for existing structures.	YES
2017: Miami-Dade County CDMP for 2020–2030 contains 12 elements, several which directly address climate change and sea level rise. The two most relevant elements are Land Use and Coastal Management. The Land Use Element states lofty goals of identifying hazard-prone areas and areas vulnerable to SLR and tidal flooding; identifying the most vulnerable public infrastructure. Revising the Land Use and Zoning Maps to take flooding and storm surge risk into account; coordinating efforts with other jurisdictions, and not subsidizing programs that encourage growth on barrier islands. This element also states that SLR projections determined by the SEFRCCC should be considered in all future County decisions regarding location, design, and development of public facilities and infrastructure.	Comprehensive Development Master Plan includes climate change adaptation measures	These goals are important first steps, but they remain to be fully implemented	YES
2017: the Office of Emergency Management of MDC released an updated of Florida Comprehensive Emergency Management Plan (CEMP). This extensive document specifies the responsibilities of the federal, state, and local governments, as well as organized stakeholders, in the face of various emergency situations that may occur and attempts to coordinate planning, response, mitigation, and recovery from identifiable hazards	Useful to identify storm surge planning zones based on current sea levels. Fosters inter-governmental cooperation.	–	YES

Table B: Miami Adaptation Efforts

(Molinaroli et al., 2019)

Miami			
Realized	Pros	Cons	Transferability
1926–1975: Construction of wood and rock groins located every block of Miami Beach	May have temporarily built up the beach	Unattractive. Blocked the natural flow of sand	–
1975–1982: Nourishment of ~17 km of beach. 1986–1988: The second phase of the project. Extension of the nourishment an 4.0 km. A total of 14,076,765 cubic meters of sand were used.	Part of Miami Beach was protected. 80% reduction in storm damage during a 100-year storm event. This project is thought to be one of the most durable replenishment projects in the US	Costly. Harm to offshore coral reef habitats. Burial of intertidal habitats	YES
2000: In response to 1992 Hurricane Andrew the State of Florida Building Commission adopted the Florida Building Code (FBC)	Stricter building standards for construction, modification and repair	Amendments every three years	YES
2014: The City of Miami Beach began to implement the MDC recommendation for SLR with the development of design standards for city infrastructure that would account for SLR during a 30–50 year time horizon. For example, basic standards were altered to increase the storm rainfall events from 15 to 19 cm during a 24 h period, and tailwater elevations were increased from 20.4 to 82.3 cm North American Vertical Datum (NAVD).	Benefits for the future	No requirements for existing infrastructure	YES
2017: Miami Beach has begun to elevate streets in areas that are most vulnerable to flooding.	Elimination of street flooding in low-lying areas	Potential flooding of businesses that are lower than the elevated streets	YES
2017–2018: Overhaul of the stormwater system in Miami Beach with the installation of 70 one-way pumps in areas that are most susceptible to flooding.	The pumps have worked during recent flooding events.	Expensive. Degradation of Biscayne Bay water quality from street runoff	YES
Recommendations and Future			
2012: Regional Climate Action Plan with 110 Action Items. Reduction of greenhouse gas emissions, and emergency management that decision-makers at the county and municipal levels can adopt to mitigate and adapt to climate change.	Although it will take many years to adopt and implement the recommendations, these are important initial planning steps	Not yet implemented	YES
The RCAP recommended that municipalities and counties develop policies and standards to improve resilience to coastal and other impacts from climate change and sea level rise and include these in their planning documents. The RCAP encouraged local governments to incorporate the concept of "Adaptation Action Area" into their planning documents, identify areas vulnerable to coastal flooding and sea level rise. An additional recommendation concerns the development of sea level rise scenario maps and flood maps that reflect the 100-year storm event under future sea level rise scenarios to incorporate into Comprehensive Planning documents.	Building and land use codes should be revised to reduce losses from new construction or redevelopment in areas vulnerable to sea level rise and flooding.	Not yet implemented	YES
2013: MDC formed the Sea-Level Rise Task Force charged with making recommendations to the County's Comprehensive Development Master Plan. The principal recommendation was to "accelerate the adaptation planning process by seeking and formally	Comprehensive Development Master Plan includes climate change adaptation measures	These goals are important first steps, but they remain to be fully implemented.	YES

Table C: Miami Adaptation Efforts 2

(Molinaroli et al., 2019)

In 2010 the Southeast Florida Regional Climate Change Compact (SEFRCCC) was established to consolidated efforts, of the flooding affected south-eastern counties of Miami-Dade, Broward, Palm Beach, and Monroe, to combat the consequences of climate change (Molinaroli et al., 2019). Two years later, in October 2012, the "110 Action Items" plan proposed various climate change mitigation and adaptation methods to make the area more environmentally friendly and increase its management capabilities of climate change (Southeast Florida Regional Climate Change Compact Counties 2012). These plans include the reduction of greenhouse gas emissions, improving water supply systems, and transformation into more sustainable communities, among others (Southeast Florida Regional Climate Change Compact Counties 2012). Miami-Dade County's Comprehensive Development Master Plan (CDMP) lays the county's development plans, by setting objectives and policies (Miami-Dade County Online Services, n.d.). To support such matters and give recommendations to the CDMP, in 2013, the Sea Level Rise Taskforce was established. They soon emphasized the importance of bringing in needed expertise to accelerate the realization of adaptation plans against the rising sea level and the increased risk of flooding (Miami-Dade County 2014). Of 12 components of the Comprehensive Development Master Plan, several components are focused on climate change and Miami-Dade county's response to the rise of sea level (Miami-Dade County 2017). There have also been collective efforts between federal agencies and local governments, such as the beach nourishment program, addressing erosion along Miami Beach, carried out by the US Army Corps of Engineers and Miami-Dade County (Molinaroli et al., 2019). The great flooding exposed Miami Beach, and in 2014 began major efforts to adapt to the rise of sea level and flooding from extreme weather events. This included tightening building standards to incorporate measures to withstand the expected increased flooding over the next 30-50 years (Molinaroli et al., 2019). These standards include the increase of the minimum elevation of seawalls from 4.76 ft to 7.26 ft and a newly added minimum elevation for yards of 6.56 ft (Molinaroli et al., 2019). Furthermore, streets are being elevated and 70 one-way pumps are installed to improve the city's stormwater system (Molinaroli et al., 2019).

Climate change and the rise of the sea level are estimated to impact tourism and as such will have cost the city of Venice around 35 to 40 million euros by 2030. Additionally, it will cause a loss of economic activity in the Venice Lagoon area of around 100 million euros by 2030. Therefore, Italy implemented three laws for the protection of Venice and the Venice Lagoon. The first is the recognition of the Venice Lagoon and its protection to be in the national interest, along with establishing an inter-institutional committee and granting them increased authority to safeguard the area (Molinaroli et al., 2019). Another law included the reallocation of national funds, to support projects such as the construction of coastal defense structures or improving on the degradation of the watershed (Molinaroli et al., 2019). The third law furthermore issued additional funds along with redefining responsibilities of the area to ensure the conservation and protection of the Venice Lagoon. Furthermore, adaptation action steps have been realized in Venice, which include raising the height of the buildings as well as improving the foundation of the city (Mancuso 2014). Compared to many other climate change-exposed cities in the world, adaption efforts in Venice date all the way back to the 16th century when the first modifications of the lagoon were made and sea barriers were constructed (Molinaroli et al., 2019). With time sea barriers became more advanced and the number of flood prevention efforts by the government increased. In order to help the local population overcome flooding events, citizens are notified with real-time information and alarms, to allow for personal preparation, for example by barricading the home's ground floors (Indirli et al. 2014). One of Venice's major adaption efforts consists of the injection of boreholes with the aim of raising the city by 25 centimeters over a 10-year period (Comerlati et al., 2004).

While it is clear to see that there are many different adaptation approaches, also some of which prove to be successful, as Varrani and Nones (2017) emphasize, it is very important for adaptation plans to be adaptable, in order to allow adjustments to changes in the environment and new research results.

2.11 Cities exposed to sea level rise

For thousands of years, humans have been settling around bodies of water. Many of the greatest cities have either been located on the coast or along rivers with easy access to the ocean. This is because not only is the ocean an important food source but also having access to the ocean provides trading opportunities. This can also be seen in the USA as many of its most important cities are located on or close to the coast. If the sea level would rise to a worst-case prediction of 3.61 feet by 2100, it would mean that around 40% of the US population would be living in high-risk flood zones (Jones, 2019). According to Zillow, there are 3.4 million currently existing homes in those future high-flood zones, and with the construction of homes continuing in the high-risk flood zones and this number will only increase (Jones, 2019). The 3.4 million current homes have a combined value of around $1.75 trillion, which is about nine percent of the US economy (Jones, 2019). In eight US states, more homes are being developed in high-risk flood zones than in low-risk flood zones (Jones, 2019). While one would imagine that due to the data on climate change and the rise of the sea level, future homes would be built in areas that are not exposed to flooding, this clearly shows that people desire to live in areas close to the coast still outweighs the potential risks associated with the home being located in such an area. For example, in Pompano Beach, Florida, 97.7% of all new houses are constructed in high-risk flood zones (Jones, 2019). This trend is very dominant in the rapidly growing Miami-Fort Lauderdale-Palm Beach area. Fort Lauderdale is also building 90% of its not houses in high-risk flood zones, in addition to 73.4% of current houses already being in high-risk flood zones. All of Davie, Florida, and Miramar, Florida, new houses are being constructed in flood-exposed areas (Jones, 2019). According to (Climatecentral, 2019), Florida leads the way for most flood-exposed homes in the US, with over 1.5 million homes being at risk of inundation, ahead of New Jersey with 282,354, Virginia with 167,090, Louisiana with 157,050, and California with 143,217 homes at risk (Climatecentral, 2019). Some of the communities and cities with the most houses in high-risk flood zones and the highest total value of homes include:

Cities housing numbers in high-risk flood zones							
	All Housing				New housing		
City	Total Units	Unit Percentage	Total Value	Value Percentage	Units Percentage	Value Percentage	Ratio High-risk vs Low-risk
Tampa, FL	18,260	16.20%	$11,084,477,888	29.90%	19.10%	34.20%	1.46
Huntington Beach, CA	12,136	21.30%	$12,404,124,125	23.20%	8.00%	12.20%	0.31
Boston, MA	29,534	25.00%	$39,167,817,339	37.40%	18.30%	74.00%	1.72
Clearwater, FL	10,233	25.60%	$5,976,288,086	47.40%	14.30%	53.00%	1.89
Virginia Beach, VA	42,293	29.60%	$16,482,749,465	34.80%	36.90%	44.30%	1.51
Jersey City, NJ	16,921	35.30%	$16,568,025,211	52.40%	16.80%	67.90%	0.75
Honolulu, HI	40,405	38.00%	$27,162,518,458	16.10%	5.80%	8.70%	1.48
Cape Coral, FL	32,898	42.50%	$11,468,787,539	52.80%	72.50%	82.70%	1.33
Miami, FL	50,816	46.90%	$25,507,729,986	48.20%	17.20%	53.20%	0.96
Charleston, SC	22,845	50.60%	$13,409,123,763	62.30%	50.20%	67.90%	1.07
Norfolk, VA	29,856	51.60%	$7,865,157,705	60.00%	51.70%	56.00%	1.10
Fort Lauderdale, FL	48,205	73.40%	$26,670,397,210	75.50%	90.10%	90.00%	2.99
Hollywood, FL	30,533	59.80%	$12,090,411,970	70.00%	40.80%	71.80%	0.58
Hialeah, FL	46,721	90.70%	$11,609,490,525	88.40%	99.70%	99.60%	50.50
Pembroke Pines, FL	52,551	94.50%	$16,103,259,854	94.80%	50.00%	72.30%	0.60
Miramar, FL	35,074	95.20%	$12,093,132,682	96.30%	100.00%	100%	

Table D: Cities Housing Numbers in High-Risk Flood Zones

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Data From: (Zillow 2018)

2.12 Real Estate market in high-risk flooding zones

As discovered throughout this research, many cities and coastal areas in the USA are exposed to flooding and in risk of inundation with the rise of the sea level. Nevertheless, the values of homes located in such high-risk flood zones are growing faster than homes in any other location (Bachaud, 2022). On the other hand denial rates for houses in high-risk flood zones, are higher than the US average denial rates. This, however, is not significant enough to be able to clearly identify the disinterest of mortgage providers to accept applications for flood-exposed properties (Bachaud, 2022). In general, it can be stated that climate change risks, do not seem to impact mortgages on or demand significantly, however, according to Zillow, climate risks are starting to affect the buyer's and lender decision-making, as both mortgage denials and mortgage withdrawals in flooding exposed areas are increasing (Bachaud, 2022).

Coastal living is one of the most desirable areas for people and this has not gone unnoticed by investors. Mortgage applications for coastal investment properties have increased (Bachaud, 2022), however, fewer are becoming primary residences. At the same time down payments on houses in high-risk flood zones are lower than the

average (Bachaud, 2022). Both these points indicate that buyers want coastal properties in flood-exposed areas, however, due to the increase in investment properties compared to primary residences and the lower down payment, it can be speculated whether this is due to the climate risks in those areas. According to Zillow, such trends are the strongest in areas of flood risk, while other markets affected by climate risks such as fire, drought, and heat do not reflect such trends. The percentage changes are so small that might seem insignificant, but they can be viewed as indicators of what can be expected for the future of the real estate market in high-risk flood zones.

While it is clear that buyers and lenders are merely influenced by flood risk, there are steps that need to be taken for mortgages issued in flood-exposed areas. A FEMA-issued Standard Flood Hazard Determination Form (SFHDF) assesses if a house is in a Special Flood Hazard Area (SFHA), and if this is the case the borrower is required to obtain flood insurance for any federally backed or regulated lender (Kunreuther et al., 2018). As explored in an earlier paragraph, this is a way of dispersing the risk among multiple parties. Even though Bachaud (2022), stated that overall values of properties in high-risk flood zones are growing faster than those in safe zones, other studies have found that homes located in the SFHA, which are required to buy flood insurance, are sold for less than the equivalent home located outside such zone (MacDonald et. al. 1990; Harrison et al. 2001; Bin et al. 2008; Daniel et al. 2009; Bernstein et al. 2019). Furthermore, some studies also argue that more flood-exposed properties are experiencing a decline in price appreciation (Tibbetts and Mooney, 2018; Kusisto, 2018). From 2005 to 2017 this decrease in home price appreciation has totalled around $16 billion dollars worth of lost appreciation due to flooding (Firststreet.org, 2019). In Miami-Dade County, Florida, homes that might not be directly affected by flooding, however, whose nearby roads are commonly exposed to flooding, have seen an average value depreciation of roughly $3.70 per square foot from 2005 to 2016 (Firststreet.org, 2019). In Florida, 22% of the state's total $1 trillion GDP, comes from real estate (American Flood Coalition, 2020). Being a state with no individual income tax and low sales taxes, its governments rely on property taxes. With a large portion of communities in Florida becoming flood exposed, and data showing a slowed

appreciation or even depreciation of property values in such areas, this could significantly impact the state's economic health (American Flood Coalition, 2020). While flooding from hurricanes is different from flooding from tidal events or sea level rise, data from its effect on the real estate market is to a certain degree representative of flooding's impact on the real estate market. Beracha & Prati (2008), analysed the real estate market trend following a hurricane. The common trend that they found was that for the first two quarters following the event, the affected real estate market takes a negative hit, seeing both property values, as well as transaction volumes, decrease. However, this dip is usually followed by a positive correction, bringing both property values and transaction volumes, back to their prior trend line, within one year of the event. Beracha & Prati (2008) furthermore state that the temporary dip after the event, presents a buying opportunity for many and as a result, the market quickly corrects back to its prior to the event level. This shows that the home buyers are merely put off by the potential risks and historic events such as prior hurricanes, but instead are more driven by buying opportunities and the desire for coastal living. As seen throughout this section, different studies show different data and different outcomes. This could be due to the measurement methods, or the locations of the studies carried out, however, due to contradicting data it is not possible to identify a trend that is true for all coastal US communities. Real Estate organizations are not only carrying out studies on the impact of the rising sea level but also starting to add features informing buyers about the flood risks of homes. Realtor.com are providing the Federal Emergency Management Agency's flood assessments along with Flood Factor's flood risk assessment (Hersher & Sommer, 2020). Leslie Jordan, the product senior vice president at Realtor.com clarifies the decision to inform customers about flood risk, saying "The more transparent we can be about these properties, about all the data about them, the more consumers will trust us as a legitimate source to make their home buying decisions" (Hersher & Sommer, 2020). Realtor.com wants to use the information to gain customers' trust, and while others websites, such as Redfin and Zillow acknowledge the importance of such information, they still decide not to provide customers with such information, in fear of decreasing values of homes already located in such high-risk flood zones (Hersher & Sommer, 2020).

3 Methodology

Instead of collecting new data, secondary data and existing literature will be used and analysed. This is because the topic of climate change is widely researched. Vigorous and prolonged studies having been conducted, providing the in-depth data that is needed for this thesis. This is also the case for data about the US real estate market. Since, this study does not focus on a single group of houses or one neighborhood, but instead on whole cities and even areas within the US, it is not realistic to gather such data individually assessing each property, but alternately data from real estate services, such as Zillow or Redfin, and reports by US governmental institutions, will be used. Therefore, a majority of the thesis is a literature review and literature analysis. A theory about climate change will be chosen, whereafter it will be tested through the data and information from scientific sources. After the assessing of the support of data to the theory, a case study will be presented to display the theories effects with a real-world example. A similar approach will also be used when examining climate changes impacts on the US real estate market, where the theory will be discussed first followed by the case studies. Even though it is the aim to explore the impacts on the US real estate market as whole, the effect which the climate has varies throughout the US and as such overall conclusion can be drawn. However, to better understand how it really effects the real estate market a more narrowed down approach will be applied. Through the use of case studies, the thesis intends to shift from a more general exploration of climate change's effect on the US real estate market to a more specific setting, examining the past, present, and future impacts of sea level rise, as well as the human response to such in a specific area. The research questions will be explored and answered to provide A SWOT analysis that will be used further analyse the Miami Real Estate market in regard to the flooding risks that the city faces. The thesis will be structured in the following order: Climate change, people's attitude toward climate change, flooding in the US, impact on the US real estate market including the case studies of Miami and Tampa, and lastly followed by the discussion

and analysis. This will build the three main sections of the thesis of: Literary Analysis, Case Study Analysis, and the Miami SWOT Analysis.

3.1 Research Limitations

Basing a study only on previous literature allows to use scientific data, collected with the help of resources beyond what was available for this study, however this approach also has its limitations. First, there is a limitation to the number of available articles which are relevant to this thesis topic. While peer-reviewed sources provided almost all of the theoretical aspects of the research, in order to gain access to the most recent data on sea level rise and the US real estate market, non-peer-reviewed sources were used. This data, however, is still trustworthy, since in most cases it comes from the largest US real estate platforms, such as Zillow and Redfin, or directly from governmental institutions. When collecting primary data, data collection can be modified to fit the needs, however, when gathering secondary data, the researcher is forced to work with the data as it is provided and cannot adjust the process or clarify in case of uncertainties. Since the information gathered throughout the literature analysis, is developed by another researcher, such information can be subject to a bias of the previous researcher. Furthermore, since this thesis researcher analysed vast numbers of previous studies and most relevant findings were used, the process of deciding what information to use also allows for bias. This could be avoided through primary data collection as the researcher then only is presented with one set of data and cannot choose. If there is only one study conducted on a specific topic, it is not possible to test the evidence for accuracy, without conducting primary data collection on the same topic.

4 Results and Key Findings

Climate Change
People's perception of climate change is widely spread, with some believing it's a myth while others believe the world will become inhabitable if necessary action is not taken. This is also the case among politicians, and thus leads to inefficiencies when changes in
Temperatures are rising faster within the artic circle than compared to the rest of the hemisphere leading to increased melting of ice and snow in such areas (Jiang et al., 2020)
Increased absorption rates of long-wavelength energy, reflected by the Earth's surface, due to the increase of trace gases (greenhouse gases), emitted by human activity, are what is believed to be the main reason for global warming (Hardy, 2003)
While the greenhouse effect well represents the process of global warming and thus has a negative connotation, it is crucial for maintaining a habitable temperature on Earth
Many of the world's largest cities are located coastal and would be directly impacted by the rise of the sea level
US Real Estate Market
By 2100, 40% of the US population could be living in high-risk flood zones (Jones, 2019)
US has the highest value of total assets exposed to flooding in the world (Jones, 2019)
Real Estate Developers keep building in high-risk flood zones, despite the current and increasing risks of flooding in the future
US real estate market seems unfazed by the risks of a rising sea level in most parts of the nation with occasional signs of a negative impact
Flood protection is more likely to be received by the least socially vulnerable than the most socially vulnerable (Martinich et al., 2012)
Property values are negatively impacted by major flood events, however usually recover to previous values within 1-2 years (Beracha &
Inundation and regular flooding could lead to major property value decreases, as developed areas could become merely inhabitable
US government has a more passive approach toward flood adaptation than other high-income countries such as the U.K., Japan, and the Netherlands (Hallegatte et al., 2013; Hanson et al., 2010)
Commercial and Residential Real Estate is the fourth biggest polluter in the US, of greenhouse gases emissions by the economic sector
The risks associated with flooding for owner-occupied homes in the US are spread among multiple stakeholders, including the property owner, insurance provider, and lender among others

Table E: Result and Key Findings

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5 Discussion:

5.1 Research Questions & Sub-questions

As seen throughout this paper, there have been many studies completed on the flooding costs, community losses due to inundation, and the value of properties exposed to flooding. Furthermore, studies have shown what areas of the US will be most impacted as well as which groups of people and how many of them will be impacted by the rise of the sea level. Also, studies have shown how cities as well as real estate developers adapt to the challenges of climate change, showing how future real estate projects and city planning are being adjusted to combat the likes of sea level rise and flooding. The main aim of the study was two answer the two research

questions of “What impact does climate change have on US real estate market” and “What are the consequences of global sea level rise on the real estate markets of coastal cities in the United States”. While both research questions are still fairly broad, five more narrow sub-questions were created, which are better able to be answered through the use of data and furthermore build the basis for answering the research questions. The five sub-questions are stated below.

- Will properties, which are affected by the consequences of sea level rise, decrease in value, due to their risk of flooding or inundation?
- How does flooding risk affect the homeownership rate, compared to the rental rate, in coastal communities?
- How does flood risk affect mortgage approval rates in high-risk flood areas compared to the rest of the USA?
- Does the rise of the sea level lead to a decrease in demand for properties located in flood-exposed communities?
- How does climate change affect the Real Estate Market in Miami

After completing the research for this study, it is possible to present trends and likely future scenarios however it is not possible to provide a definite answer, as it is simply impossible to accurately calculate values or outcomes of the future without knowing exactly what events and to which extend they will occur. Additionally, it is not clear how the future of adaptation and flooding prevention will look. While overall the USA seems less concerned and less proactive to the rise of sea level and other climate-related risks, than other nations, they also possess resources greater than many nations to act if they want to do so. Actions are already being taken in many parts of the US coastal areas, yet still, there is a common presence of the techno-market imaginary among the leaders, believing that the free market will turn the challenges of climate change into opportunities and produce the needed solutions to overcome such challenges.

Will properties, which are affected by the consequences of sea level rise, decrease in value, due to their risk of flooding or inundation?

This is very likely to be the case in the future when flooding becomes more severe. Real Estate markets in the US are already seeing declines in property values of flood-exposed areas (Firststreet.org, 2019) What is more likely in nearer future and in flood-exposed areas when such are still liveable is that the value of such properties will appreciate less than those properties not exposed to flooding (MacDonald et. al. 1990; Harrison et al. 2001; Bin et al. 2008; Daniel et al. 2009; Bernstein et al. 2019). The US real estate has had periods in which the average value of properties has decreased, such as during the financial crisis in 2007-2008, however looking at the history of the US real estate market, properties are getting more and more expensive. As have the majority of goods and services due to inflation. Therefore, unless areas become inhabitable and the homes in such places become worthless, it should be expected that offer a longer period of time, even flood-exposed properties will continue increasing their values. This is also backed by the high demand for coastal properties, which even in some places has driven the property values of houses in high-risk flood zones higher than the equivalent house in safe zones. Here, however, it can be assumed that this is due to the buyer's willingness to pay a premium for my being close to the water and not due to flood exposure. Many of the high-risk areas that have seen a greater appreciation than safe zones are areas of high income and low social vulnerability. These properties are also more likely to retain value in the future as they are more likely to benefit from adaptation projects than other social groups (Martinich et al., 2012). As can be seen on the Gulf Coast of people living in inundation-risk zones, only 92% of the least vulnerable are expected to be protected, however, only 1% of the most vulnerable can anticipate such help. This means that unless something changes or they themselves can find ways of protecting themselves against inundation, their homes are likely to become worthless.

How does flooding risk affect the homeownership rate, compared to the rental rate, in coastal communities?

Compared to buyers, where flood risk information must be provided in most US states, landlords are not required to share information about the flood risks in all but one state, Georgia (Hersher, 2020). There the landlord needs to notify the tenant about the risks, only if the property was flooded 3 or more times within the prior 5 years (Hersher, 2020). This indicates that renters are less aware of the flood risks of their rental property, which could takes away a negative aspect in their decision-making process compared to buyers. Furthermore, mortgage applications for investment properties compared to primary residences are increasing (Bachaud, 2022). This could indicate that more people are buying properties in order to rent them out and profit from the coastal housing demand, however, this is not sufficient enough information to determine whether homeownership rate and rental rates will change due to flooding risk.

How does flood risk affect mortgage approval rates in high-risk flood areas compared to the rest of the USA?

Federally backed mortgage providers and regulated lenders are becoming more cautious with mortgages issued in flood-exposed areas. As a result, mortgage applicants have to go through the process of the FEMA-issued Standard Flood Hazard Determination Form to determine whether the property lies within a Special Flood Hazard Area. If this is the case the mortgage recipient is required to acquire flood insurance. As discussed earlier in the thesis, stakeholders of properties are trying to spread the risk associated with the property among multiple parties, minimizing their own risk. Therefore, it can be stated that the risks of flooding have made lenders more alert to the risks, however, a more significant impact of flood risk on mortgages could be seen through changes in mortgage approval rates in such areas. According to Zillow mortgage denial rates in high-risk flood zones are higher than the US average (Bachaud, 2022). However, this difference is not significant enough to be to conclude that flood risk leads to lower mortgage approval rates, as well as, there was no data

found proving that the flood risk is the cause of the higher denial rates and not other variables.

Does the rise of the sea level lead to a decrease in demand for properties located in flood-exposed communities?

Coastal living has always been very high in demand, people want to live close to the water and many even pay big premiums to do so. The information about flood exposure is available to the buyers and is even part of the buying process as many need to buy flood insurance. Many areas have already experienced several flooding events, with some facing such on a regular basis, yet most of such areas have only grown in population, while the fewest see people decline in demand because of this. Even though Florida, and in particular the city of Miami, is one of the most exposed places to flooding and extreme weather events, it is experiencing a strong population growth with people and companies moving there. Hurricanes tend to depreciate real estate values and transaction volumes of the affected areas, however, after a year these tend to be back at prior to the event levels, showing little to no effect on the demand in the long run. Therefore, it should not be expected that the demand for properties in high-risk flood zones will diminish unless those areas and their liveability are severely impacted, as for example, it would be of inundation.

How does climate change affect the Real Estate Market in Miami?

Climate change and the rise of sea level are already affecting Miami and its real estate market at the time of conducting this study. Extreme tides occasionally flood parts of the city, with western Miami Beach being one of the most exposed areas, on average being flooded 6 times a year (Molinaroli et al., 2019). Daily flooding could, however, very soon already be the new standard, as according to predictions made by the Union of Concerned Scientists (2017) this could already be the case by 2045. Therefore, the Miami Real Estate market is already adapting as the city laid out new building

standards to withstand such flooding events, including increased minimum elevation of sea walls and a minimum elevation for yards of 6.56ft, which reflects in development costs (Molinaroli et al., 2019). The city of Miami has seen one of the largest property values in of any big city in the US in 2022, ranking third with an average increase of 28.1%, and thus the real estate market seems little to not affected at all by the flooding risks (Hansen, 2022). However, studies have shown that once streets become regularly affected by flooding, their surrounding properties tend to decrease in value (Firststreet.org, 2019). Therefore, it can also be expected that if western Miami Beach does not prevent its streets from becoming regularly flooded, the property values will be negatively impacted. To further understand how the Miami real estate market is impacted by natural forces and how it is positioned compared to the risks of flooding due to sea level rise, a SWOT analysis is created.

There are many different variables that affect the real estate market, most importantly the demand. While it is possible to compare data on demand from the past and how it increased or decreased with certain events, demand will always be determined by the individually identified wants and need, and thus the property prices are regulated by a buyer's subjective value. Therefore, while previous trends can make be used to make future predictions, the real estate market is based on the information of home values being distressed by flooding, it can be advised that the state of Florida accelerates its sea level rise and flooding prevention actions in order to protect its people and their homes before property values are negatively affected. There are many studies that have shown that flooding risks do affect property values, and if it does not decrease the value it slows down the property's appreciation compared to non-flood exposed properties.

5.2 Miami Real Estate Market SWOT Analyses

A SWOT analysis is created to analyse the Maimi real estate market in regard to the risks of climate change.

Miami Real Estate Market SWOT Analysis	
Strengths Financial resources Available data, research, and information	**Weaknesses** Current adaptation to flooding risks Location (Elevation, Natural Barriers, Landscape) Expansion of market is quicker than adaptation response Already occuring flooding events Land available for expansion Dimensions of flood-exposed properties Land subsidence
Opportunities Federal Support Demand of individuals and companies to move to Miami Green Infrastructure	**Threats** Rising sea level Future flooding events and potential inundation Loss of property values and tax income Population displacement Time Extreme weather events (Hurricanes, Heavy Rainfall)

Table F: Miami Real Estate Market SWOT Analysis

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The weaknesses and threats, strongly outweigh the strengths and opportunities of the market. Even though the SWOT is an objective representation of the information known to the researcher, and thus can vary based on the researcher and research conducted, it provides an overview of the current position of Miami and its Real Estate Market.

Strengths:

Miami has a thriving economy. As of October 2022, Miami-Dade County had an unemployment rate of 1.7 percent, which is the lowest in all of Florida and well below the national average of 3.7 percent tidal Miami has seen an increase of 7.9 percent in private-sector jobs in the last year increasing to a total of 1,130,900 such jobs, which is also the fastest growth of all US Metros (DEO, 2022). Among other data, this just

shows the economic strength of the city as people and companies keep moving to the city. According to UBS 2018, Miami is one of the richest cities, with its purchasing power ranking 3rd in the world. Miami does have also has a quite high rate of poverty, with 21.5 percent, however overall it can be concluded that Miami is a wealthy city (*Poverty Rate in Miami, Florida*, 2021). With most tax rates currently being relatively low, Miami has the financial resources and capabilities to support major flood prevention efforts if needed. Additionally as already demonstrated throughout this research data on the sea level rise and its effects are in abundance and most likely will continue being gathered as well as updated, due to the federal agencies continuing to gather and provide such to local governments to support their adaptation work (Molinaroli et al., 2019).

Weaknesses:

One of the major weaknesses Miami has is that flooding is not a risk for the future but is already a reality in parts of the city today. Western Miami Beach experiences flooding during extreme tides about 6 times a year (Molinaroli et al., 2019). This is even though adaptation efforts, such as the elevation of the streets and the improvement of its stormwater system through the installation of 70 new pumps, have been implemented, this has not been enough to stop prevent flooding from occurring (Molinaroli et al., 2019). This shows that Miami from a current standpoint has not managed to implement sufficient adaptation measures to combat the flood events it experiences and thus is not up to date to the point where it successfully can protect its city from flooding. To make matters worse, the population of Miami-Metro keeps growing, and this is happening at rates quicker than the city can implement adaptation efforts. This is mainly because many of the new homes are built in areas that are in high-risk flood zones. The likes of Miramar and Davie have 100% of new homes built in high-flood risk zones (Jones, 2019). This furthermore adds to the large dimension of flood-exposed properties in the Miami area which are exposed to flooding. A reason for the expansion of the metro happening in high-risk flood zones is that there is no other land for the city to expand on and this is why Miami's location

is arguably its biggest weakness. To the east, there is the Atlantic Ocean, to the west the Everglades, to the south sits Biscayne Bay, and to the north, the agglomeration of developed land already stretches about 90 miles to the city of Jupiter. Additionally, there is little to no elevation throughout the metro to provide natural protection against flooding. 90% of Miami city has an elevation of fewer than 6 meters, and 25% sits below 1 meter in elevation (Molinaroli et al., 2019). Lastly, parts of Miami are experiencing land subsidence, causing the areas of land to gradually sink, due to the movement of underground material (Fiaschi and Wdonski, 2016; NOAA., n.d.). Some parts of the city have sunk up to 24 centimeters since the first recordings when the city was established. This shows that Miami has many weaknesses and as such this area, with a sea level rise of 0.5 meters by 2070 would have the highest value of total assets exposed to the risk of flooding in the whole world (Nicholls et al 2007).

Opportunity:

Similar to the strengths, of Miami its opportunities mainly lie in the potential to further improve its current strengths due to external opportunities. The demand for people and companies to be located in Miami continues to be very high and as a result of this, the city will be able to continue growing its economy. Most importantly, however, those people will need places to live and the companies places to operate from. This is an opportunity for the Miami real estate market to grow and increase in value. Secondly, there are several federal agencies aiming to assist local governments in their fight against the consequences of climate change, as well as federal grants to financially support local adaptation capabilities. Lastly, a opportunity for the city in preventing flooding and thus protecting its properties, is through transitioning to a more green infrastructure supporting both mitigation and adaption. For example, as has already been tested in other places around the world, vegetated building exteriors slow down the surface runoff during rainfall, alleviating the load on Miami's drainage system (Tremeac et al., 2012). Additionally, it would also positively contribute to the city's air quality and provide natural protection against the heat, helping decrease the use of air-conditioning.

Threats:

Rising sea level is a problem that Miami will be majorly affected by in the future. It poses a big threat to the city of Miami as well as all of the Miami-Fort Lauderdale-Palm Beach metro area. According to NASA (2022), the east coast will experience a sea level rise between 25 and 35 centimeters in the next 30 years (Younger, 2022). By 2070 the sea level rise could very likely be around 50 centimeters and lead to 300,000 people being displaced to regular flooding and inundation in Miami-Dade County alone US. Displacement of such large groups of people will affect the tax income and as areas become inhabitable property values will vanish. Already today studies have found that property values in Miami-Dade County of homes which are located nearby commonly tidal flooded roads have seen a depreciation in value of around $3.70 per square foot between 2005 and 2016 and while other studies have shown some flood-exposed areas have had less property value appreciation than the equivalent in areas not exposed to flooding (Firststreet.org, 2019). About 22% of Florida's GDP comes from the real estate sector and with the state relying on property taxes, loss of property value poses would pose a major threat to its economy (American Flood Coalition, 2020). As we can see rising sea level and the increase in flood risk, creates a snowball effect of threats to Miami. Another threat that is much less controllable or possible to prepare for is extreme weather events such as Hurricanes. Around half of the twenty most damaging hurricanes that affected the USA, were in Florida (Pile et al. 2008). Hurricanes can cause physical damage to properties throughout large areas through its wind as well as the flooding they can cause, and therefore, always poses a big threat to Floridians and their properties.

6 Conclusion:

It was the aim of this thesis to explore and answer the two research questions. The answer to research question number one “What impact does climate change have on US real estate market” was build throughout the study by analyzing and presenting how cities like Miami and Tampa are already affected by the rising sea level. The main risks, which already impacts the US and its real estate market today, is the increased risk of flooding. A risk which not affects the US as much today, however is predicted to become a consequence of the rising sea level and as such also is an important aspect affecting the answer to research question number two “What are the consequences of global sea level rise on the real estate markets of coastal cities in the United States” is the potential of areas experiencing inundation. While many places in the world already experience an increased risk of flooding, for example through tidal flooding in Miami, in which extreme tides flood areas of Western Miami Beach around 6 times a year (Molinaroli et al., 2019), a new and more severe risk from the rise of sea level is that of inundation. Inundation would permanently submerge areas of land underwater making them merely inhabitable for most human beings. If the sea level would rise by 67 centimeters by 2100 around 6,000 square miles of US land could be lost through inundation (Martinich et al., 2012). This is roughly the size of Hawaii and more than the likes of Connecticut, Delaware, and Rhode Island (*United States by Area*, n.d.). In Florida alone, this would put over 1.5 million homes at risk of inundation (Climatecentral, 2019). Therefore, it is clear that adaptation efforts can protect some people, however, it seems impossible to protect such a large mass of land. This is why mitigation is crucial, to prevent the rise of sea level from ever reaching such heights. When it comes to protection against flooding and inundation, there is a very clear trend toward who will be the recipient of the protection. The least socially vulnerable, also the wealthiest neighborhoods are most likely to first be the beneficiaries of flood protection efforts, while for example on the Gulf Coast, 99% of the most socially vulnerable are expected to not be protected, forcing the inhabitants of such areas to abandon their homes (Martinich et al., 2012). This shows that those who already have very little could very likely lose their homes and the little wealth that they have without any help from the government. On the other hand, the

majority of those considered wealthy and the least socially vulnerable, will be able to continue living in their homes and not lose their assets to inundation. Even with the planned adaptation efforts, a rise in the sea level as predicted would lead to drastic consequences for the US and its coastal communities. By 2070 it could displace around 300,000 people in Miami-Dade County alone, with that number stretching far into the millions across the USA (Hanson et al. 2011; Hauer et al. 2016, Treuer et al. 2018). Along with that, sea level rise could cost, individuals as well as the government immense amounts of financial losses, if not stopped or the needed protection implemented. 45 percent of the US total GDP comes from coastal counties and disruption to this through flooding or inundation, could cause severe damage to the US economy (Kildow et al., 2014). As of the time of writing this thesis, 2023, the effects of the sea level rise and flooding only affect the real estate market minimally, however, the first signs of its negative effect can be seen, such as an increase in mortgage application denials or the decrease in property appreciation in areas of flood exposure compared to those without (MacDonald et. al. 1990; Harrison et al. 2001; Bin et al. 2008; Daniel et al. 2009; Bernstein et al. 2019; Bachaud, 2022). Once the problems of flooding become more troublesome to the people living in such areas due to more regular occurrences of flooding and more visible to everyone else, demand, and as a result of that property's values, could decrease rapidly.

6.1 National Recommendations

As seen, the problems which a rise of the sea level to the predicted levels would cause are alarming and potentially humans could not protect themselves through adaptation alone. Therefore, it is strongly advised that mitigation efforts need to be treated with the highest priority all around the world to stop the current trend of global warming and thus also, if not preventable, at least decrease the rate of sea level rise to give countries more time to prepare for the risks which a rise of the sea level will bring. It is difficult to give adaptation recommendations on a national level since all cities and communities do not share the same scenarios. For some communities, the most feasible solution to rising sea level is to relocate since they do not have the

resources to protect themselves against flooding, however, for major metropolitans such as New York, Boston, or New Orleans, relocating this is not an option. For such cities heavily investing in adaptation efforts will be key. A change which would make a big impact, is making climate change goals and implementation plans an integral part of the national focus without the intervention of short-term serving politicians. This is because, politicians tend to make decision which help them gain support for the voters. Climate change plans need implementation and execution on a time scale much longer than that of a politician. Therefore, when changes among the political leaders occur, this can create inefficiencies among climate change plans or even lead to the termination of such plans, as was seen when Donald Trump took over as the new president of the United States of America and decided to abandon the previously established plans, under Barack Obama. This is not unique to the US and has happened in other places of the world. Therefore, a different governance system regarding the fight against climate change would be beneficial, however how such should be setup is worth a study of its own.

6.2 Miami Recommendations

A city such as Miami, which is a wealthy city, is already behind with its flood prevention efforts, not being capable of protecting areas of the city against tidal floods. With predictions of such same areas being flooded around 380 times a year, in only a little over 20 years, in 2045, and many adaption efforts taking years to implement it is clear to see that time is a vital problem in the fight against sea level rise (Union of Concerned Scientists, 2017). Therefore, it is important that both mitigation and adaptation plans are acted upon in a more consequent manner, by governments, businesses, as well as the individual. However most crucially to bring mitigation efforts to a level where global warming is stopped because adaptation efforts alone will not be enough to protect Miami in the long run. It is recommended that the city is very prudent about their future developments. These should be built with the ability to withstand sea level rise and be able to still operate as normal when flooding does occur. Furthermore, they should be developed with sustainability as

vital aspect of the development. As was discovered, the real estate industry is the US fourth biggest green house gas emitter by economic sector and therefore, plays a relative significant part in creating the problem of sea level rise. Lastly, Miami suffers from land subsidence, due to the movement of underground materials. It should become a primary focus of addressing such problem, as the already minimal elevation of the city along with the subsidence, accelerates process of Miami becoming increasingly flood exposed.

6.3 Study Limitations

Since no primary data was collected for this thesis, and all findings are based on secondary data, it was difficult to stick with one specific scale when analysing the impacts of sea level rise on the real estate market. For example, for the case study of Miami, some secondary data is based on the municipality of Miami, while other data is based on the Miami-Dade County or even the Miami-Fort Lauderdale-Palm Beach Metro area. As such, for the SWOT analysis, it was difficult to draw conclusions from one specific scale only; therefore, it was based on Miami the city, and the area around it. While there is an abundance of available research on sea level rise and real estate, there are very limited sources of information that analyse the exact topic of "sea level rise effect on us real estate market". Therefore, connections need to be identified and sometimes leaving questions unanswered due to a lack of information. The scale was occasionally unclear, where data was presented for Miami, however without identifying what scale of Miami it represents. Since climate change, along with the knowledge available to humans about it, constantly is evolving, some of the findings may not be the most up-to-date, or potentially become incorrect if new findings disprove the current theories about climate change. What was very clear throughout the research process, was that there were never exact numbers on how much the sea level will rise, but instead ranges from the best-case scenario to the worst. With the future rise of the sea level being a process that still needs to take place, the conclusions drawn throughout this study are based on predictions for the future,

rather than on results of the past. This means that variables could still alter future outcomes and thus proving both the predictions and conclusions inaccurate.

6.4 Future Research Implications

Compared to many other studies which collect primary data, this study does not provide new data for future researchers. This is because only secondary data was used during this thesis. What makes this study so useful and beneficial for other researchers and people who want to explore the consequences of sea level rise on the US real estate market, is that information from different topics were combined into one study addressing such potential risks. While many studies have been conducted on climate change and the rise of the sea level, as well as several on the US real estate market, there is a lack of studies drawing the connections between the two. That is what this study does, as its main focus is to assess how climate change affects the US real estate market, however, it also looks at how the US real estate market affects climate change. This study can also be appealing to those who do not intend to conduct their own studies, but instead just want to understand what risks a rising sea level could pose, or live or work in areas discussed in this study and want to know how they could be affected in the future. By building a thorough understanding throughout the study, with background education provided, such as for example by clarifying “what is climate change” or “what are the differences between mitigation and adaptation” this study is also easily understandable by the reader without prior knowledge. Lastly, this study could also become very beneficial for home buyers, homeowners, or investors looking at the Miami real estate market. This is because this study will provide them with current data, as well as predictions, regarding flooding and how the real estate market reacts, or could react to such complications in the future.

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