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The Economic Cost of Climate Change in the United States of America

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<p>Climate change is a serious global problem with environmental, sociocultural, political, and economical impacts and consequences. It is not just a problem for the future generations, negative effects of climate change and global warming can already be seen in all regions around the world. The aim of this thesis was to examine the economic cost of climate change in the United States of America.</p> <p>The data for this thesis was gathered by researching and analysing current literature and other sources on the related topics. Climate Change is a very dominant theme, and emerging number of up to date evidence, studies, news, and other type literature was easily accessible.</p> <p>The findings from this research and the range of published evidence suggest, that the climate change will have severe negative impacts on the economy of the United States. The frequency, severity, and consequences of extreme weather events are expected to intensify as a result of climate change. These events cost billions of dollars, and U.S. citizens, businesses, and infrastructure are suffering from the consequences. Extreme weather is not the only problem disrupting the U.S. economy. Water quantity and quality, agriculture, forestry and fisheries, human health, and tourism are all affected by the climate change and global warming.</p> <p>The true economic costs of climate change in the United States are uncertain. As global temperatures will most likely continue to rise and problems associated with climate change will quantify, the related costs will multiply.</p>	
Keywords	Climate Change, Global Warming, Economy

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Glossary

CDC	Centers of Disease Control and Prevention
EPA	United States Environmental Protection Agency
GDP	Gross Domestic Product
NASA	National Aeronautics and Space Administration
NCA	National Climate Assessment
NCAR	National Center for Atmospheric Administration
NCEI	National Centers for Environmental Information
NDMC	National Drought Mitigation Center
NIDIS	National Integrated Drought Information System
NOAA	National Oceanic and Atmospheric Administration
NRDC	Natural Resources Defense Council
NSSL	National Severe Storms Laboratory
UCAR	The University Corporation for Atmospheric Research
USDA	U.S. Department of Agriculture

1 Introduction

Like many others, I first learned about climate change in 2006 after watching the documentary: *An Inconvenient Truth*. The eye-opening documentary was directed by Davis Guggenheim, who followed former United States Vice President Al Gore's educational campaign about global warming. I was 10 years old. Taking care of our planet has been a very important matter to me ever since. Understanding how the climate and our environment is changing is important, so we can prepare for the future.

Scientific research has acknowledged a human caused climate change as a serious threat to the environment and human societies. Climate change is a global issue with environmental, sociocultural, political, and economic impacts and consequences that must be understood. Most of the Americans do believe in climate change, are worried about global warming, and think it will harm future generations. However, more than half of the people living in the U.S. believe, that global warming will not harm them personally. The aim of this study was to create a deeper understanding of the impact of climate change on the United States' economy.

Climate change or global warming doesn't just harm the environment, it will also cost a lot of money. What many people don't realise is that climate change also affects food production, water supply, extreme weather events among many other things. Regardless of what some Americans think, climate change is already affecting the United States, and the taxpayers and federal government are paying for these costly consequences.

This thesis is divided into six chapters, and the study begins with this introductory chapter. The second chapter contains general information about climate change and global warming. What is the main reason for this phenomenon and how it is affecting our planet. Third chapter will introduce and cover all extreme weather events in the United States that are related to climate change. These events include heat waves, drought, wildfires, hurricanes, strong winds, and flooding. Costs of these events will be analysed and several case studies introduced. In chapter four, other national climate topics and problems will be introduced and analysed. Topics covered in this chapter

are water scarcity, agriculture, forestry, fishery, human health, tourism, and who is paying for the climate change in the U.S. The fifth chapter will dive into the future of climate change and the last chapter includes the conclusion and some further discussion.

2 Climate Change and Global Warming

Climate change is a change in the climate that can last for several decades or even longer. Most of the climate changes that the earth has experienced, are due to small variations in our planet's orbit. These variations change the amount of solar energy the earth receives. Climate has been changing very drastically during these past few decades and our earth is becoming considerably hotter. The warming is also happening much faster when compared to previous climatic changes. Even though the earth's climate has changed throughout our history, majority of the scientist do agree that the significant changes we have seen recently are caused by human activities. (Climate Council, 2017)

The climate change and global warming we are experiencing right now, are caused by the excessive amount of greenhouse gas emissions entering the earth's atmosphere. Since the Industrial Revolution that began in the 18th century, greenhouse gasses have built up in the atmosphere. These built-up gasses are trapping more heat close to the earth's surface. Energy, agriculture, industrial processes, and waste are some of the industries and activities that are heavily contributing to the climate change and the production of greenhouse gas emissions. (Climate Council, 2017)

According to the data from the Global Carbon Project, United States is the world's second biggest polluter after China. (Global Carbon Atlas, 2018) Climate change has already taken a heavy toll on the environment. Extreme weather events have become more frequent and severe, sea levels are rising, plant and animal species are under the threat of extinction, and new diseases will spread. In the next chapters, we will go through these consequences and see how they are impacting the United States' economy.

3 Extreme Weather and Natural Disasters in the U.S.

Extreme weather and different climate events have become more frequent in recent decades, and current research indicates that some of these increases are due to human activities. As a result of global warming extreme weather conditions are getting more intense and frequent in United States as well. The country is very vulnerable to natural disaster and every year these climate events kill thousands of people and cause the economy to lose billions of dollars. Especially the number of heat waves, heavy rains, wildfires and hurricanes has increased noticeably in the United States. These events can cause physical damage to infrastructure, time element losses such as business interruptions, agricultural losses, and damage to human health. In the next few sections the economic effects of heat waves, drought, wildfires, hurricanes, strong winds, and floods will be discussed in more detail.

3.1 Heat Waves

A heat wave is an extended period of inordinately hot weather. According to the U.S. Global Change Research Program, heat waves in the U.S. are occurring more often than they used to. In 50 major U.S. cities, the average heat wave season is currently 47 days longer than it was in the 1960s. In this measure, 46 of the 50 metropolitan areas experienced a statistically significant rise in the frequency of heat waves, and 45 experienced significant changes in the duration of the season between the 1960s and 2010. As the global warming and climate change progresses, heat waves are expected to become even more common and intense. The increase of heat waves can lead to more severe and frequent droughts, wildfires, and heat-related illnesses and deaths. Heat waves also increase the demand for electricity significantly. (U.S. Global Change Research Program, 2021)

According to the U.S. Centers of Disease Control and Prevention (2019), over 600 people are killed by extreme heat in the United States every year. According to the National Weather Service, heat waves have caused more fatalities over the past 30 years than all other weather related natural disasters combined. It is more likely that heat waves impact individuals who work or live outdoors. Half of all U.S. employees have jobs that require them to be outside, the Bureau of Labor Statistics (2017) reports. Workers

who are heavily impacted by the heat waves work in leisure and hospitality, construction, logistics, and agriculture. Extreme heat lowers work productivity significantly.

Heat waves dry out vegetation and create tinder for fires. During the past years, extreme heat has already contributed to the wildfire seasons in the United States. In the next few sections, impacts of drought and wildfires will be examined more closely. Heat itself, can also lower food production by destroying crops, which will cause food prices to spike. In addition to hot weather affecting the crop growth, it will promote invasive pests and species, reduce livestock forage quality, and lead to changes in land use across the nation. (Ogburn et. al., 2014) According to the U.S. Department of Agriculture, in 2019 agriculture, food, and other related industries contributed \$136.1 trillion to the United States GDP, a 5.2 percent share. In 2019 10.9 percent of U.S. employment was generated by agriculture and its associated industries. (USDA, 2020)

3.1.1 The Cost of Heat Waves

Heat waves have disastrous effects on human health and labour, nature, agriculture, and storm weather patterns. Heat waves also imply greater demand and cost for electricity. During the heat waves electricity demand rises because buildings and apartments need to be cooled. The price of power is influenced by the growing demand for electricity. Extended periods of time where the electricity demand is much higher than the average level of supply will cost millions of dollars. For example, in June 2017, the cost of electricity nearly doubled in Phoenix (AZ) due to severe heat. An average household in the city spent over \$50 more on electricity in June 2017 compared to June 2016, with only one percent increase in average per kWh price. The same phenomenon was seen in different cities and states across the U.S. during the same year. According to the EPA, the demand for energy that will be used for cooling is predicted to increase by about 5-20% if the nation's climate warms by 1 Celsius (1.8 Fahrenheit). (Arcadia, 2018)

Excessive temperatures affect human health and performance. Extreme heat can lead to dehydration, heat exhaustion, significantly slower and worsen work productivity, and increase the risk of accidental injuries. According to Natural Resources Defense Council in 2006, a heat wave that lasted over two weeks caused 655 deaths and 16,000 emergency room visits in the U.S., resulting in nearly \$5.4 billion dollars in costs. (NRDC,

2011) According to a study conducted by National Institutes of Health, the total median charges for a patient hospitalised with a heat-related illness in the U.S. between 2001-2010 were \$8,965 (\$5,017, \$17,047). (Schmeltz, Petkova and Gamble, 2016)

Millions of Americans have occupations that require them to work outdoors, exposing them to extreme weather and heat every year. According to the Environmental Protection Agency, heat is expected to cost the U.S. workforce 1.8 labour hours per person by 2100, equating \$170 billion in lost wages. According to the U.S. Bureau of Labour Statistics, excessive heat killed 783 U.S. workers and injured 69,374, between 1992 and 2016. (Drugmand, 2018)

Heat threatens and damages United States' agriculture on a wide scale. Droughts and heat waves have already destroyed one-tenth of the world's cereal crop between 1964 and 2007. Every year in the U.S. heat stresses livestock and fisheries and farmers have to pay a lot of money to combat the spread of pests, weeds, and fungi caused by high temperatures. High night-time temperatures can also lower crop yields. As an example in 2012, a warmer winter in Michigan caused cherry trees to bloom too early and cost the industry over \$220 million. (Drugmand, 2018)

3.1.2 CASE STUDY: Chicago Heat Wave 1995

In mid-July 1995, a record-breaking heat wave struck most of the United States' Midwest, with the Chicago area becoming particularly hard hit. The heat tied or broke a series of temperature records from July 12th to July 16th, 1995. The heat reached its highest on July 13, with a high of 40°C (104°F) and a low of 27°C (81°F) at O'Hare Airport, for an average of 34°C (93°F). The heat index, which is a measure of temperature and humidity, reached 48°C (119°F). Approximately 750 lives were lost over a five-day period, making it Chicago's deadliest weather occurrence in history. The combined and accumulated effects of multiple days of extreme heat, high humidity, strong July sun, and trapping pollutants took a severe toll on Chicago residents. The extreme weather and heat also affected Chicago's infrastructure adversely. (NOAA, 2019)

Over the five-day period, over 700 Chicago citizens' lost their lives and thousands of people had to be taken to local hospitals due to heat-related issues such as dehydration,

heat strokes, and heat exhaustion, putting a strain on the city's health-care system. (AdaptNY, 2016) On July 12th, 13th, and 14th, 1995, the Commonwealth Edison power system encountered record demand for electricity. A power outage occurred in some areas due to the high volume of electricity. Firefighters also had to hose down drawbridges over the Chicago River so that they could work and shut properly. The heat caused many roads to buckle. Residents opened up to 500 fire hydrants in the city, resulting in low water pressure and high costs. (NOAA, 2019)

Heat-related illnesses resulted in high public health costs during the heat wave. According to one study, during the week of Chicago heat wave in 1995, there were 11% (1072) more hospital admissions than average comparison weeks. People were treated for dehydration, heat strokes, and heat exhaustions. (Semenza et al., 1999) The 1995 Chicago heat wave happened over 20 years ago, and there are no estimations of total costs. As mentioned earlier, according to one study, the total median charges for a patient hospitalised with a heat-related illness in the U.S. are \$8,965. Let's imagine that all excess hospital admissions during the heat wave totalling in 1072, were caused by heat-related illnesses. This would mean that excess health care costs resulted in over \$9.6 million during those few days, not including 750 deaths. The real health care costs have probably been a lot higher. It is a fact, that 1995 Chicago heat wave also resulted in higher electricity costs, lower work productivity and higher water demand. These costs have not been recorded or reported.

3.1.3 Forecast

In the United States, excessive summer heat is rising and will be more intense and frequent in the future. Heat waves will become more frequent especially in Great Lakes areas, Midwest, and West of the United States. (Hosmay et al., 2018) For example in Montana, heat wave days are projected to increase to 50 by 2050, compared to average of 10 heat wave days in early 2000's. On the other side of the U.S., Michigan will experience 23 danger days with heat index above 41 Celsius (105 Fahrenheit) by 2050, compared to 2 days in the beginning of 2000. (States at risk, 2021)

If emissions are not significantly reduced, scenarios project that by the 2050s, today's worst heat waves will become ordinary summer days. In the future, heat-related

temperature changes will cost billions of dollars in terms of damages, taking into account risks to health and mortality, economic damage, and cooling costs. At the moment, taxpayers are the only bearer of these expenses. (Drugmand, 2018) As mentioned earlier, heat is also expected to cost the U.S. workforce 1.8 labour hours per person by 2100, equating to \$170 billion in lost wages. The extreme heat will also increase the risk of other types of natural disasters such as wildfires in the future significantly.

3.2 Drought

A drought is a period of time when below-normal precipitation occurs in a certain area or region. The lack of sufficient precipitation, either rain or snow, may lead to decreased soil or groundwater humidity, decreased stream flow, crop damage, and a general scarcity of water. Droughts after hurricanes are the second-most expensive weather occurrences. Droughts can last for weeks, months, or even years. It is also often difficult to identify when a drought has begun or when it has ended, unlike sudden weather events such as thunderstorms or hurricanes. (National Geographic Society, 2013)

The consequences of drought often ripple through communities, economic sectors, and ecosystems, leaving a wide spectrum of impacts behind. Drought reduces agricultural productivity. It causes crops to fail, wells run dry, and forage for livestock might be scarce. Even though farmers bear the most direct stress from drought, often the costs are spread more widely to consumers and taxpayers. In addition, drought reduces urban water supplies and increases the risk of wildfires. Increasing populations and communities in chronically water-short areas such as the western U.S., are more dependent on regular precipitation, which contributes to sensitivity of drought. (NDMC, 2021)

Overall, the United States has a significant supply of water, but it is often not located where it is needed, or when it is required. The demand for water in the US is really high, and in fact the country is one of the world's largest withdrawers of water per capita. Water shortage is a problem with both economic and political implications and the shortages in the U.S. have disrupted relationships between states and water users. (Nantz, 2014)

3.2.1 The Cost of Droughts

Effects and costs of a drought tend to be often underestimated since the event is slow-developing and rarely involves direct property damage. Droughts are very expensive and in 1995 the Federal Emergency Management Agency estimated that droughts cost the U.S. an average of \$6-8 billion every year. (NDMC, 2021) According to National Centers for Environmental Information (NCEI) only hurricanes are more costly than droughts. Since the 80's, United States has experienced 26 droughts with overall damage costs of more than \$1 billion. These 26 droughts have cost the country \$249 billion in total, and the estimated cost of each of these events have been more than \$9.6 billion. Most deaths associated with drought are caused by heat waves. (NIDIS, 2020)

Drought is one of the most devastating climate events that threatens the agricultural production of the United States. Drought can rapidly lead to reduced crop yields or even to total crop losses. Crops can also become more vulnerable to pests, as the soil moisture decreases. Even short-term droughts can cause significant damage, especially when they occur during key stages of crop development, such as flowering or right after planting. Lower yields result in higher consumer prices, and raised prices for local food will result in increased reliance on imported food. Reduced water availability may also lead to consumer health issues, as the farmers aren't able to wash and sanitise their products. (Holupchinski et al., 2021)

3.2.2 CASE STUDY: Midwest Drought 2012

In 2012, the central Great Plains experienced the worst drought since 1895. The drought was worse than 1930s Dust Bowl's driest summers. As air currents struggled to carry seasonal rainfall from the Gulf of Mexico, it contributed to the drought that struck the southern Great Plains in 2010-2011. The dry weather resulted in record heat waves, causing corn yields to plummet to levels similar to those seen in the 1930s. A natural disaster was declared by the U.S. Department of Agriculture in over 2,245 counties, covering 71% of the country. (Amadeo, 2020)

The Midwest drought of 2012 was a multibillion-dollar agriculture crisis. According to NCEI figures, the 2012 drought caused \$30 billion in damages, harm being mostly

agricultural. Grain corn losses were most substantial, but also row crops and sorghum were hit hard by the drought. Even more drought tolerant soybeans experienced a 9% yield reduction. Overall, the United States is expected to have lost nearly 4 billion bushels of corn, 170 million bushels of soybeans, and 87 million bushels of sorghum, based on declines from pre-drought production figures. (Rippey, 2015)

The livestock industry was another agricultural field in the United States that was greatly affected by the 2012 drought. At the height of the 2012 drought, 76% of the domestic cattle inventory was located in drought area, according to USDA report. In August–September 2012, the USDA announced that 59 percent of U.S. rangeland and pastures were ranked in extremely poor to poor condition for five weeks in a row, the highest percentage ever registered during the 1995–2015 era of record. (Rippey, 2015) Because the drought withered crops in the field, many farmers were forced to butcher their cattle that had become too costly to feed. (Amadeo, 2020)

As a result of the 2012 drought, parts of the once-humid east started getting drier and farmers had to start growing drought-resistant crops. This also suggests that the 1930s Midwest dust storms, which were caused by a mixture of environmental patterns and human actions, could happen again. (Amadeo, 2020)

3.2.3 Forecast

Climate change is playing a big role in the increasing frequency of droughts in the United States. Changing climate can also amplify the effects. Since drought destroys plants, there are not roots to keep the soil in place when it rains. By causing new flow patterns, rainfalls can cause bigger and more regular flash flooding. Wildfires are also much more frequent and severe due to dead vegetation, and warmer and dryer weather. Especially the Western states have already become more vulnerable to drought and longer wildfire seasons. (NIDIS, 2020)

According to a study by Aiguo Dai from the National Center for Atmospheric Research (NCAR), the U.S. and many other densely populated countries face an increasing danger of extreme and sustained drought in the coming decades. By 2030, if climate change is not halted, the United States will be much drier. (Dai, 2010)

3.3 Wildfires

A wildfire is an uncontrolled fire that burns in an uncultivated land, often in rural regions. Wildfires can burn in the vegetation, both in and above the surface. Typically, ground fires burn in soil that is rich with organic matter that fuels the flames. These fires can smolder even for an entire season, until the conditions are right for expanding to a surface or crown fire. Surface fires burn in dry and dead vegetation that grows above the ground. These fires are often fuelled by fallen leaves or parched grass. Even though wildfires can start anytime or anywhere, either due to a natural occurrence or a human-made spark, the weather conditions such as wind or high temperatures will most likely determine how much a wildfire grows. (National Geographic Society, 2019)

Wildfires are a normal and essential part of healthy ecosystem. Wildfires can clean up and nourish the forest floor and in addition kill insects and diseases that harm vegetation and trees. Even though wildfires are an important part of nature's natural cycle, climate change has left some ecosystems more vulnerable to flames. Warmer temperatures are intensifying droughts and drying out forests. Especially the southwest U.S. has been suffering more dangerous and deadly wildfires during the last years. (National Geographic Society, 2019)

Forests, shrubland, and grassland together occupy more than half of the United States' land area. These ecosystems are very important to the country, both economically and environmentally. Climate change threatens these ecosystems as the frequency, severity, and the extent of wildfires increases. The National Interagency Fire Centre has reported an average of 72,000 wildfires in the U.S. every year since 1983. Since the 1980s, also the total land burnt by wildfires each year has increased. The amount of land burnt by wildfires differs by state. In the western United States, fires destroy more land than in the east. Nine of the ten years with the most acreage burnt have occurred since 2000, according to statistics from the National Interagency Fire Center. Wildfires have the potential to cause significant damage to property, livelihoods, and human health, particularly as urban areas extend into wildland areas. (US EPA, OA, 2016)

3.3.1 The Cost of Wildfires

Wildfires can impact and hurt communities, environment, human health, and the economy. The true costs of wildfires are often a lot greater than the costs reported to the public. Wildfire expenses go beyond the number of acres burnt and the number of days or weeks it takes to put out a fire. Millions of dollars are spent to extinguish wildfires in the U.S. every year. In addition to these costs, impacts to ecosystems, infrastructure, watersheds, businesses, individuals, and human health have to be taken into consideration. These costs include more specifically property losses, several different post-fire impacts such as erosion and flooding, air and water pollution, injuries and fatalities, lost local business revenues, infrastructure damages and shutdowns (airports, highways, railroads, etc.), and plenty of other ecosystem service costs that could extend into the remote future. (Western Forestry Leadership Coalition, 2010) According to 2017 analysis by U.S. Department of commerce, the annualised cost of U.S. wildfires range anywhere between \$71.1 billion to \$347.8 billion. These numbers include direct losses of infrastructure and rebuilding as well as indirect costs such as hit to the tourism, tax base, and deaths. (Thomas et al., 2017)

3.3.2 Case Studies

Case studies below provide more detailed analyses of costs associated with specific wildfires from different years. Three separate wildfires are briefly examined; the first case is from Oregon (2002), the second one is from Arizona (2011), and the third one from California (2018). These wildfires were high-profile events that had significant economic and ecosystem losses. All of these fires were located in the western United States and total cost figures were affected by a number of factors, including the magnitude of the event, local population density, and terrain.

CASE STUDY 1: Biscuit Fire, Oregon 2002

The Biscuit Fire was a severe and massive wildfire ignited by lightning strikes in 2002. Five fires were found in the Siskiyou National Forest during a three-day period starting

July 13th. The Biscuit Fire destroyed over 500,000 acres in southern Oregon and northern California. The fire lasted almost for five months and it wasn't officially declared extinguished before December 31, 2002. Biscuit Fire is believed to be Oregon's largest and most costly forest fire of record, costing over 150 million dollars in suppression efforts. (LaLande, 2019)

Just the cost of containing and suppressing the Biscuit Fire reached \$150 million. Luckily most of the burned area was located in the wilderness, however commercial forestland and infrastructure were threaten. Firefighters from Mexico and technical staff from Canada, Australia, and New Zealand were among the over 7,000 people who served out of three major fire camps In August. Before that, a range of forest fires burning elsewhere in the West had been employing most of the country's available firefighting resources. (LaLande, 2019)

A historic fire lookout and less than a dozen structures, mainly cabins or mining claims and small plots of private property in the Kalmiopsis, were destroyed by the fire. There were no casualties as a result of the fire or the firefighting operation. (LaLande, 2019) The Biscuit Fire was one of the most expensive wildfires in the West's history, but as mentioned earlier the true cost of a wildfire is often even greater than the cost reported to the public. Direct costs, which in this case were 150 million dollars do not include post-wildfire rehabilitation costs, indirect costs such as property value losses, or addition costs such as healthcare costs caused by increased respiratory problems.

CASE STUDY 2: Wallow Fire, Arizona 2011

The Wallow Fire began on May 29th 2011, in Arizona, at the peak of fire season in the Apache Sitgreaves National Forests, when high southwest winds and low humidity are typical. The Wallow fire burned almost 540,000 acres during a five week period. The fire started unintentionally from a campfire. (Jeong, 2016)

According to one source, the Wallow Fire cost government agencies \$72 million to suppress and in addition \$37 million were spend on evaluation, clean-up, and restoration

activities. The value of the 32 houses and 40 other buildings lost in the fire, are not included in this figure. (Jeong, 2016) The real cost of the wildfire has most likely been several million dollars more than the estimated \$109 million. The estimated number does not include infrastructure damage costs or increased health care costs.

CASE STUDY 3: Camp Fire, California 2018

The Camp Fire, ignited by a faulty electric transmission line, started on November 8th, 2018 in Butte County, Northern California. According to the state officials, the county had experienced its hottest years on record during the past decade and the vegetation had been particularly parched due to the extreme heat, which tributed to the fire. The wildfire was the most destructive and deadliest fire in the history of California. Camp Fire was also one of the deadliest wildfires in the U.S. history, and one of the world's costliest natural disasters in 2018. On November 25th 2018, the fire was fully containment after seventeen days, due to the arrival of the first winter rainstorm of the season. (United States Census Bureau, 2018)

88 people lost their lives in the Camp Fire and many others needed to be admitted to a hospital. The wildfire burned over 153,000 acres, an area roughly size of Chicago. 18,800 structures were destroyed and around 30,000 people lost their homes. More than 5,000 firefighters were deployed to put out the flames. In January 2019, the California Department of Insurance announced \$8.4 billion in insured losses. (Boghani, 2019)

The total estimated cost of the Camp Fire was \$15 billion, primarily consisting from the destruction of infrastructure and firefighting costs. (Bartz, 2019) However these costs do not include post-wildfire rehabilitation costs, indirect costs such as property value losses, or addition costs such as healthcare costs which would significantly contribute to the total cost of the wildfire. Wildfire impacts and hurts the economy long after the fire is out, but these costs are often not included in the reports.

3.3.3 Forecast

For the last two decades, climate change has inexorably stacked the table in favour of larger and more destructive fires across the American West, as science and studies have shown. Increasing temperatures, shifting rain and snow cycles, variations in vegetation, and other climate-related changes have increased the risk of fires igniting more often and burning more rapidly and extensively than in the past. The greatest correlation is with rising air temperatures. Global average temperatures have risen by around 1.8 degrees Fahrenheit since the industrial revolution in the late 1800s, but in California the shift is closer to 3 degrees Fahrenheit. Warming has accelerated every decade and the temperatures are predicted to continue to increase in the future. Since the 1970s, the western fire season has been prolonged by at least 84 days. (Borunda, 2020) According to the Fourth National Climate Assessment (NCA) Vol 1., climate change is currently responsible for more than half of the increase in forest fuel aridity, and the increased dryness has doubled the amount of land burned by wildfires in the U.S. since 1970. (Bartz, 2019)

According to data from the National Interagency Fire Center, federal wildfire response costs in the United States have increased from an annual total of around 425 million dollars from 1985 to 1999 to 1.6 billion dollars from 2000 to 2019. State suppression costs have increased as well; in California, the total annual suppression costs have nearly doubled and reached about 400 million dollars in the last decade. (Roman, Verzoni and Sutherland, 2020)

3.4 Hurricanes and Strong Winds

According to the National Ocean Service, a hurricane is a type of storm called a tropical cyclone. These types of storms can form over tropical or subtropical waters. Tropical cyclones are rotating low-pressure weather systems with organised thunderstorms, but no boundaries separating two air masses of different densities. When the maximum sustained winds of a storm exceed 119 kph, it is considered a hurricane. (NOAA, 2019)

Hurricanes originate from the Atlantic region, which comprises the Atlantic Ocean, Gulf of Mexico, Caribbean Sea, the eastern North Pacific Ocean and, less often, the central

North Pacific Ocean. Hurricane season lasts from June to November, while hurricanes may, and have occurred beyond this time frame, on average 12 times a year in the Atlantic Basin. (NOAA, 2019) In the United States, tropical cyclones can create impacts from Texas to all the way to New England. The impact area can also include other inland states where the hurricane can result as an extreme rainfall or inland flood damage. (NIDIS and NOAA, 2020)

Hurricanes can cause intense winds, waves and tornadoes, but floodwaters are the most dangerous aspect of these type of storms. When a hurricane approaches the coast, the sea level can increase by as many as 20 to 30 feet (around six to nine meters). Ocean water is pushed towards the land by the storm's wind. Storm surge, or rising water, has the ability to submerge low-lying areas and towns along the coast. Storm surge, when combined with the storm's crashing waves, destroys docks, homes, roads, and erodes beaches. Storm surge floods are normally short-lived, lasting just few hours, but they can do a great deal of harm. The extent of destruction is determined by the storm's intensity and what it hits. When a hurricane enters a coastal area, it has also the potential to move inland. The storm has usually weakened by this time, but it can still inflict damage. Rivers can flood and mudslides may occur as a result of the storm's torrential rains. (UCAR, 2021)

3.4.1 The Cost of Hurricanes and Strong Winds

Since the 1980 to 2021, tropical cyclone losses have been dominating the distribution of damage of the United States billion-dollar disaster events. According to NOAA, tropical cyclones represent the second most frequent disaster event types after severe storms. Tropical cyclones have the highest total expense per occurrence, with an average \$19.2 billion per event, and the most damage in total has been caused by 52 tropical cyclones totalling in \$997.3 billion. Hurricanes are accountable for marginally more than half (53.1%) of all billion-dollar disasters in the United States, but they account only for 18.2 % of the billion-dollar occurrences that National Oceanic and Atmospheric Administration has analysed since 1980. Severe storms have been causing considerable damage during the years with an average cost of \$2.2 billion per event. Most of the disaster related deaths are caused by tropical cyclones accompanied by extreme storms. (NOAA, 2021)

Global warming is an important cause for the rising costs, but so are the growing number of population and material wealth over the past few decades. The fact that most of the development has occurred in a more vulnerable areas such as coasts or near rivers complicates these trends even further. (NIDIS and NOAA, 2020)

3.4.2 Case Studies

Case studies below provide more detailed analyses of costs associated with specific hurricanes and strong winds from different years. Three separate hurricanes are briefly examined; the first case is from Louisiana (2005), the second one is from the East Coast (2012), and the third one from Texas (2017). These hurricanes were high-profile events that had significant economic and ecosystem losses. All of these hurricanes were located in the eastern United States and total cost figures were affected by a number of factors, including the magnitude of the event, local population density, and terrain.

CASE STUDY 1: Hurricane Katrina 2005

On August 29, 2005, Hurricane Katrina entered the state of Louisiana as a category 5 hurricane. Katrina was the most destructive and costliest storm in the U.S. history impacting over 90,000 square miles (23,3099 square kilometres). The height of the storm surge reached over 27 feet (eight meters). Katrina and the storm surge revealed serious infrastructure flaws in the levees of New Orleans. Flooding would have been cut in half if the levees had held. Eighty percent of the area was flooded and for weeks, the floodwaters did not recede. Hurricane Katrina's extensive damage was quite unusual. (NOAA, 2005)

Flooding in New Orleans resulted in significant property loss and 300,000 houses were completely destroyed or left uninhabitable as a result. According to NOAA, hurricane Katrina cost \$125 billion, and only \$80 billion of the losses were covered by insurance. (NOAA, 2017) Professor Bernard Weinstein from the University of North Texas, estimates Katrina's true costs to be close to \$250 billion, when both the damage and Katrina's economic impact are combined. (Florida Government Finance Officers

Association, 2017) In the third quarter, the US economy grew by 4.1 percent. Later, in the fourth quarter, the U.S. economy fell to 1.7 percent. That's when manufacturing losses, such as gas pipe faults, became evident. Fortunately, United States' economy was strong enough to overcome it. (Amadeo, 2020)

Katrina caused damage on 19% of United States oil production. When combined with hurricane Rita, which struck shortly after Katrina, 113 offshore oil and gas platforms were destroyed in total. These two storms damaged almost 460 oil and gas pipelines and spilled almost as much oil as the Exxon Valdez catastrophe in 1989. (Atkins et al., 2007) As a result, oil prices increased to over \$70 per barrel and gas prices soared to over \$3 per gallon, with reports of prices going up to \$5 a gallon. (Pan, 2005)

Katrina also affected New Orleans' tourism industry, Louisiana's sugar industry, as well as oyster and shrimping industry significantly. The port of New Orleans suffered \$300 million in damage, but was reopened to ships a week later. A year before Katrina, city's tourism industry attracted over 10 million visitors, and generated almost \$5 billion. A year after Katrina, in 2006, the city received only 3.7 million tourists. After Katrina, Louisiana's sugar industry saw a 9% drop in production, resulting in \$280 million in losses. (Amadeo, 2020)

The effect on people and animals was also significant. The death toll from Hurricane Katrina was 1,833 people. (US Census Bureau, 2015) Thousands of people went missing as a result of the storm and 200 bodies went unclaimed. 600,000 pets were killed or left stranded. 770,000 people in total lost their homes and 75,000 people returned after the hurricane, only to discover their houses had been completely destroyed. (Amadeo, 2020)

CASE STUDY 2: Hurricane (super storm) Sandy 2012

Superstorm Sandy was actually multiple storms rolled into one, making it one of the most destructive hurricanes to ever hit the United States. Sandy caused flooding, mudslides, and destructive winds in the United States' East Coast as well as in the Caribbean during

the fall 2012. The storm was three times wider than a typical hurricane, and it affected 24 different states. Sandy raged for nine days, and during that time the storm killed almost 150 people in the United States, and 70 in the Caribbean. (Gibbens, 2019)

Despite the fact that the storm wasn't as powerful as other well-known hurricanes, a mixture of weather factors and the fact that most of the area was unprepared, resulted in significant harm. Sandy is being considered to be the fourth most costly storm in United States history. (Gibbens, 2019) National Oceanic and Atmospheric Administration estimates, that the total cost of Sandy exceeded over \$74 billion. (NOAA, 2019)

Many buildings and homes were destroyed along the East Coast. 17 percent of the city of New York, in total 51 square miles flooded. More than 443,000 New Yorkers were living in that area at the time and 88,700 buildings were in this inundation zone. Buildings in the area contained more than 300,000 homes and almost 23,500 businesses. Many of the city's vital buildings, such as hospitals, nursing homes, key power facilities, and all of the wastewater treatment plants were located in that area. When Sandy hit, most of the New York City property owners were without sufficient flood insurances. The New York City government estimates that the damage inflicted on the city alone was 19 billion dollars. (City of New York, 2014) Regions of the Staten Island and Jersey Shore were also especially hit hard. Thousands of people were left temporarily homeless after the storm, and over 20,000 families were displaced a year after the disaster. (Gibbens, 2019) Sandy also closed temporarily many highways, roads, subway tunnels, and airports. (City of New York, 2014)

Sandy's effect on large urban centres resulted in extensive water and electricity power outages. Over 8 million people lost electricity as a result of the storm, with outages lasting days in some major cities and even weeks in outlying areas. Power outages were recorded as far west as Michigan as a result of Sandy. The storm also forced the New York Stock Exchange to close down for two consecutive business days. (Gibbens, 2019)

CASE STUDY 3: Hurricane Harvey 2017

On August 25, 2017, Hurricane Harvey moved over land in Texas as a Category 4 storm. According to the National Hurricane Center, Harvey is the second-most costly hurricane that has hit the United States. Harvey caused \$125 billion in damage and at least 68 people died from the direct effects of the hurricane. Another 35 deaths were also indirectly associated with Harvey. In the span of six days, Harvey made three landfalls. The hurricane lasted a record-breaking 117 hours, stalling for four days over the coast. (Blake and Zelinsky, 2017) According to the Harris Flood Control District's estimation, in only four days, one trillion gallons of rain poured down on Harris County and Houston city. At hurricane's peak, one-third of Houston was under water. (Cook, 2018)

With a population of 6.6 million inhabitants, Houston is the fourth-largest city in the United States. Harvey created particularly severe damage because it lingered over a large metropolitan area for longer than most hurricanes. The infrastructure of Houston and other areas took hard hits. The hurricane flooded over 300,000 buildings and 500,000 vehicles. Around Houston, police and emergency responders handled up to 10,000 rescue missions. (Blake and Zelinsky, 2017) FEMA estimated, that over 13 million cubic yards of debris needed to be removed after the storm. The hurricane also caused severe drinking water facility issues. At the peak of the event, 61 drinking water facilities were inoperable and 203 boil water notices were in effect. Another 40 wastewater treatment plants were out of operation, which caused a leakage of nearly 150 gallons of sewage water. In addition, 266 spills/discharges of hazardous material were tracked. (Cook, 2018)

A high proportion of the petrochemical industry is located in the hurricane-affected area. Harvey caused a quarter of the region's oil and gas production to shut down, affecting 5% of the country's revenue. Refinery activity persisted at multi-year lows for around a month after the storm. Harvey's impact caused gas prices to soar all across the country. Also a substantial portion of the plastic resins industry is based in the area. About half of the industry's capacity was offline in late August 2017, due to storm related shutdowns. (Bayard, Decker and Gilbert, 2017)

Hurricane Harvey left a very expensive path of destruction on its wake, affecting an estimated 13 million people. In the months after the flood, Texas state and city authorities prioritized debris clean-up, but overall recovery was delayed as services were redirected to Florida due to Hurricane Irma, then Puerto Rico and the US Virgin Islands due to Hurricane Maria. Because many people lived outside of the alluvial plain, the majority of those who were affected were unfortunately uninsured. Many people were relying on whatever federal state and local assistance they received to get back on their feet and restore their houses. (Huber, 2018)

3.4.3 Forecast

There are several proven ways how global warming is making hurricanes and storms worse. Global warming will most likely create more hurricanes the size of Katrina, Sandy, and Harvey. Warmer temperatures caused by global warming will allow more moisture to be held in the atmosphere. Flooding will be more likely near Gulf Coast cities as water levels increase. Climate patterns in the Gulf are also being stalled by global warming, which allows hurricanes to linger longer. (Amadeo, 2020)

According to the Environmental Protection Agency, the average global sea level has risen 22.61 centimetres (8.9 in) between 1880 and 2015. The pace is much faster than in the past 2,700 years, and the sea level has risen 4.67 centimetres (1.84 in) between 2000-2010 alone. (Environmental Protection Agency, 2015) Rising sea levels are contributing and worsening after storm flooding significantly.

The average global temperature has increased more than one degree Celsius since 1880. The temperature of the ocean's depths is increasing as well, which adds to the ferocity of a storm. Higher temperatures also increase the amount of humidity in the air and reduces the amount of winds around the storm. This phenomenon creates a greater rainfall during a hurricane, which can result in additional flooding. (U.S. Global Research Program, 2014) Climate change has been slowing down weather patterns by abetting jet streams. Since 1949, the pace of hurricanes has slowed by 10%. This will allow severe storms and hurricanes to linger over specific area for longer and create more damage. (NOAA, 2021)

According to a study conducted by the Princeton University, hurricanes will become noticeably more frequent and intense by 2035. The same study projects that there will be more than 30 extreme storms, more powerful than a Category 5. (Bhatia et al., 2018) Climate change, according to M.I.T. projections, would result in more hurricanes that escalate significantly shortly before landfall. This currently happens once a century, but by 2100, they'll happen every five to ten years. (Emanuel, 2017) More frequent and severe storms will cause the economy lose billions of dollars in the future. Most of the disaster-related costs have already been caused by tropical cyclones.

3.5 Floods

Flooding is an overflow of water on land that is usually dry. Floods may occur over a long period of time or within minutes after heavy storms, when ocean waves come to shore, snow melts rapidly, or when dams or levees collapse. Floods are the most frequent and prevalent of all weather-related natural disasters and flooding occurs in every U.S. state and region. Annually, floods kill more people than hurricanes, lightning, or tornadoes. (NSSL, 2015)

Much of the extreme flooding in the U.S. has occurred along the Mississippi River and in Texas, as well as along the Gulf Coast and in Florida. In the United States especially at risk are densely populated areas, areas near rivers and dams, areas close to mountains and steep hills, and recently burned areas. Ice jams and snowmelt can also cause a dangerous flash flood. Flash floods are the most hazardous type of floods, that combine the disruptive force of a flood with high speed. These kind of floods can also occur when heavy rainfall exceeds the ability of the soil to absorb it. Normally dry creeks or streams that are suddenly filled with water, enough to overtop their banks, can cause flash flooding. (NSSL, 2015)

Flooding often damages and destroys houses, buildings, businesses, and other infrastructure that is located in the affected area. In addition, hazardous items such as sharp debris, chemicals, oil, and untreated sewage can contaminate the water and landscape when floodwaters recede. Mold blooms that are extremely hazardous will easily overtake water-soaked structures. People who live in flooded areas can be left

without clean drinking water and power. This might lead to outbreaks of dangerous waterborne diseases such as cholera, typhoid, or hepatitis A. (Nuenz, 2019)

3.5.1 The Cost of Flooding

One of the most common, widespread, and expensive natural hazards is flooding. Losses in the United States total about \$8 billion a year. In recent decades, the death rate has also risen to more than over 100 people each year. Flooding is a natural phenomenon that has occurred for millions of years, especially in river floodplains. The Mississippi Valley, with its famously valuable floodplains, has supported agriculture for centuries. However, humans have raised the risk of death and destruction by rapidly building new houses, businesses, and other structures in floodplains that are vulnerable. (Nuenz, 2019)

Most expensive flood disasters in the U.S have been caused by hurricanes and storms. (Statista, 2021) Since 1988, the estimated total cost of flooding in the U.S. is \$199 billion. In the last three decades, intensifying rainfall fuelled by climate change has added about \$75 billion in flood damage, according to Stanford University researchers. According to the same report, the damages resulting from worsening heavy rainfalls accounted for about a third of the overall financial costs from flooding in the country between 1988-2017. According to the study, even in states where long-term weather hasn't changed, the wettest storms have already worsened and caused further financial harm as a result. (Davenport, Burke and Diffenbaugh, 2021)

Many property owners in high-risk regions are often without flood insurances because the federal flood maps that are used to guide insurance demand are often outdated and do not account for the effects of climate change and heavy rainfall. (Davenport, Burke and Diffenbaugh, 2021)

Flooded areas will often require expensive long-term help. Affected areas in most cases need financial aid for restoration of buildings, business recovery, and environmental clean-up. Help is also needed to bridge the difference between insurance payouts and actual costs, since most homeowner ´s insurances do not cover damage caused by flooding. In addition, funding is usually needed for remediation of mold in flood-affected

areas. A lot of people might also need long-term mental health and trauma support after a disaster. Farmers who are in financial distress as a result of the flooding or crop losses due to destroyed or late harvest will need financial assistance. (CDC, 2019)

3.5.2 CASE STUDY: River Flooding 2019

There were 14 billion-dollar climate-related events in 2019. Floods along the Mississippi, Missouri, and Arkansas rivers were responsible for three of them. These floods affected nearly 14 million people, with another 200 million at risk. From spring to early fall, the Mississippi River flooded for the longest time on record, shattering the 1927 Great Flood record. Between March and September, there were three significant flooding events. In several cases, towns were flooded many times with no time to clear up or brace for the next flood. (CDC, 2019)

Hundreds of houses were damaged or abandoned in flood-affected areas. Even minimal flooding can require extensive repairs. According to FEMA, one inch of water in a home causes \$25,000 in damage. More than \$1,172,000 was distributed by the Midwest Early Recovery Fund to counties impacted by flooding. 14 organizations from several different states were among the grantees. (CDC, 2019)

According to the USDA Farm Service Agency, 19.3 million acres of crops were left unplanted in 2019. Due to the harsh conditions, almost 11% of the 175 million acres of arable land in that part of the United States remained unplanted. In 2019, crop losses totalled at least \$400 million, with livestock losses totalling \$440 million. (CDC, 2019)

According to NOAA's annual 2019 National Climate Report, flooding on the Mississippi River and its side streams in Missouri, Illinois, Nebraska, Iowa, and nine other states resulted in an approximate \$6.2 billion in damage in 2019. 2019 Midwest flooding was the 51st most expensive natural event since NOAA started keeping track of costs. (NOAA, 2020)

3.5.3 Forecast

Climate change is increasing the risk of flooding in the United States, especially in low-lying and coastal areas. Temperature rises associated with global warming will cause hurricanes to travel more slowly and bring more rain, funnelling moisture into atmospheric rivers. Meanwhile, the sea levels are being elevated by melting glaciers and other causes, posing long-term and persistent flooding threats. According to a 2017 estimate, more than 670 U.S. cities will experience regular and frequent flooding by the end of this century, with more than 90 coastal communities already experiencing the consequences. (Nuenz, 2019)

According to a research conducted by First Street Foundation, almost 4.3 million residential homes around the United States currently face a significant flooding risk that could cause economic harm. The Foundation discovered that while the estimated projected annual loss for these properties in the United States is \$20.0 billion in 2021, the amount will rise to almost \$32.2 billion in 30 years (2051). This means an increase of 61% as a result of the changing climate (First Street Foundation, 2021)

According to projections and analysis by UCS, more than 300,000 homes worth a total of \$117.5 billion in coastal cities around the United States are expected to be at risk of chronic tidal floods over the next 30 years. The study projects that the number will grow to 2.4 million homes and more than \$1 trillion in property loss by the end of the century, and these numbers are focused entirely on existing homes. (Sauter and Frohlich, 2021)

3.6 Overview

Extreme weather events are disrupting the U.S. economy across the nation. The chart below, shows average costs of each climate event.

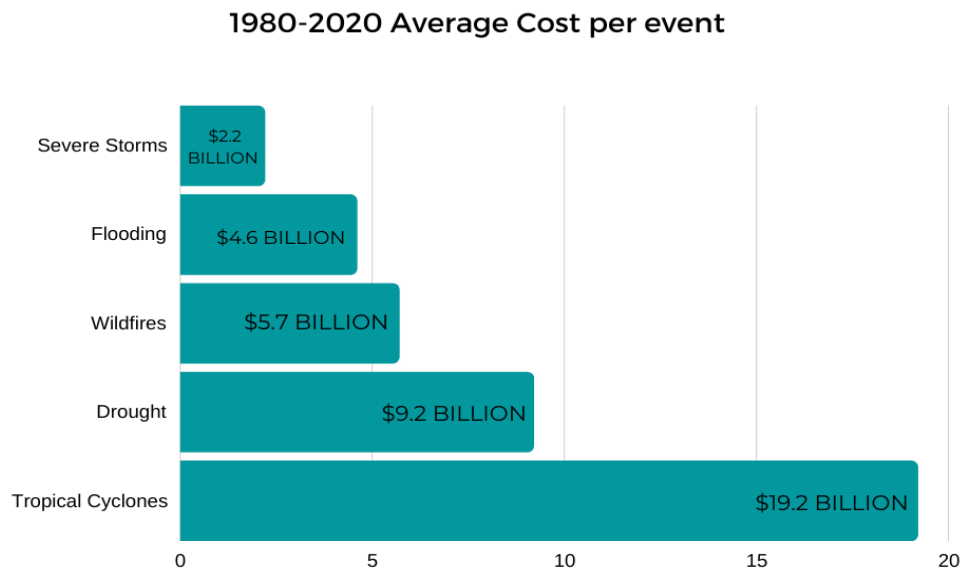


Figure 1: 1980-2020 Average Cost per Event (Data Source: NOAA, 2021)

As mentioned earlier and seen in Figure 1 above, tropical cyclones are the most costly climate disaster events in the United States. Tropical cyclones have the highest total expense per occurrence, with an average \$19.2 billion per event. The most damage in total has been caused by 52 tropical cyclones totalling in \$997.3 billion. Followed by tropical cyclones, the most expensive event types according to NOAA are drought with a median cost of \$9.2 billion per event, wildfires with a median cost of \$5.7 billion per event, and flooding with a median cost of \$4.6 billion per event. The average cost of a severe storm is \$2.2 billion. (NOAA, 2021)

1980-2020 Distribution of Costs by Disaster Type

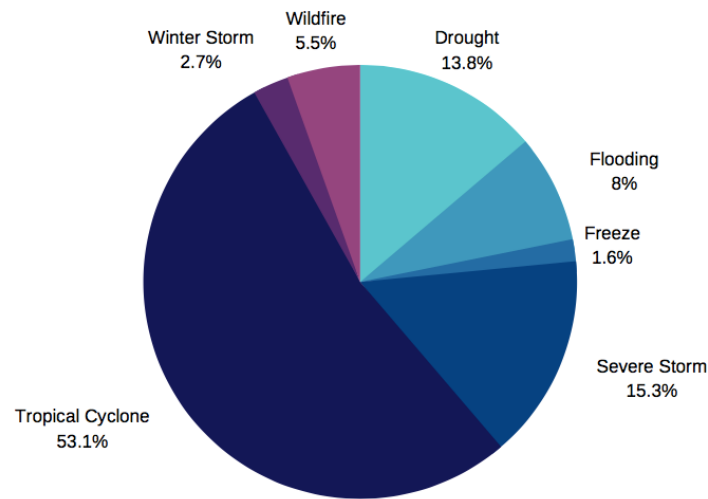


Figure 2: 1980-2020 Distribution of Costs by Disaster Type (Data Source: NOAA, 2021)

As shown in Figure 2, the distribution of costs by disaster type is very uneven. Between 1980-2020, over 50% of the financial damage was caused by Tropical cyclones. 15.3% of the total costs were caused by severe storms, 13.8% by droughts, 8.0% by flooding, and 5.5% by wildfires. (NOAA, 2021)

3.6.1 Billion-Dollar Climate Disasters in the U.S.

Natural disasters are already taking a heavy toll on the U.S. economy, but according to many studies and predictions, the country will suffer even more in the future. National Oceanic and Atmospheric Administration has been tracking billion-dollar weather and climate disasters since 1980. Since 1980, U.S has experienced 285 billion-dollar disasters in 50 different states. The total cost of these 285 disasters is 1.875 trillion U.S. dollars. During 41 years, 14,485 people have lost their lives in these events. (NOAA, 2021)

Number of Billion-Dollar Disasters by Time Period

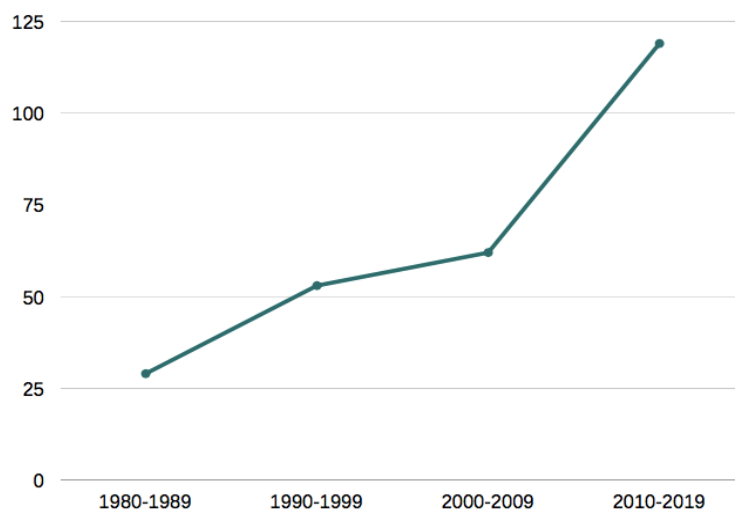


Figure 3: Number of Billion-Dollar Disasters by Time Period (Data Source: NOAA, 2021)

As we can see from the Figure 3, between the years 1980-1989 in the U.S., there were 29 (2.9 per year) billion-dollar climate disasters in total. The total cost of these events was \$178.1 billion. Figure 3 also shows, that from 1990 to 1999, there were 53 events (5.3 per year), costing the U.S. economy \$274.0 billion. After the year 2000 the costs and number of events have started to increase even more rapidly. During 2000-2009, the total cost of the events had already doubled from the last decade. During that time, there were only 9 more events compared to previous ten years, but the total cost of these events was \$519.0 billion. During the next decade between the 2010 and 2019, also the amount of events has doubled. During that time the U.S. experienced 119 billion-dollar events, costing the country over 810 billion dollars. (NOAA, 2021)

United States has experienced 285 billion-dollar climate disasters. Almost 18% of these disasters (50 disasters in total) have happened during the last three years. The year 2020 set the new annual record with 22 billion-dollar events. 2020 was the sixth consecutive year (2015-2020), in which U.S. had been hit by ten or more billion-dollar weather and climate disaster events. These events included 13 severe storms, 7 tropical

cyclones, one drought, and one wildfire. As a result of these climate disaster, 262 people died and affected areas had major economic consequences. Over the last 41 years there has been nine years (1998, 2008, 2011-2012, and 2015-2020) with ten or more independent billion-dollar climate disasters. (NOAA, 2021)

It has to be taken into consideration, that these numbers only include the most expensive climate events. NOAA's estimations do not reflect the total cost of country's climate and weather disasters, which is lot higher. For example, according to Statista, in 2019 United States experienced 88 climate and weather related natural disasters. (Statista Research Department, 2021) It should also be noted, that climate change is not the only factor that is driving the cost of these events up. Increases in population and material wealth over the past decades are also major factors for higher damage potential.

3.6.2 States that are More Prone to Extreme Weather

The United States of America consists of 50 states. While each region of the country is affected by a unique combination of climate and weather events, since 1980, every state has been hit by at least one-billion dollar disaster. However, one state really stands above the rest. According to NOAA's analysis, Texas has experienced more than 100 individual billion-dollar disasters. The state of Texas is especially vulnerable to hurricanes and storms, floods, wildfires, and extreme heat. Also the state of Florida and Louisiana are exposed to hurricanes and flooding. (NOAA, 2021)

California is also a state that stands out from the rest. California's historic wildfires and problems with associated air pollution have dominated the headlines in recent years. In California, the wildfire season has become longer and now it lasts all year around.

4 National Climate Topics and Problems

Increasing natural climate disasters are not the only problem that is disrupting the U.S. economy. Climate change and global warming are also affecting United States' water quantity and quality, agriculture, forestry and fisheries, human health, and tourism. Especially U.S. agriculture sector is very vulnerable to climate changes. Country's water

supplies will become very stressed in the future and we can expect diseases such as Malaria and Zika to enter new territories. Tourism could suffer billion dollar losses due to disappearing winters, submerging coastal cities, and poor air and water quality which discourages tourism.

4.1 Water Scarcity

Climate change impacts United States water in complex ways since global warming is altering almost every stage of the water cycle. Country's drinking water supplies, food production, land values, and so forth will be impacted. Warmer air has a greater capacity for retaining moisture than cooler air. As a result, the air will absorb more water from seas, streams, soil, and plants. The drier conditions left behind by this air have damaging impacts on agriculture and drinking water sources. Warmer, wetter weather could put human lives in jeopardy. By blocking the cooling effect of our sweat, higher humidity will make potential higher temperatures intolerable in some areas. Warmer temperatures and increasing acidity are making life very difficult for sea and lake creatures as well. As already discussed in previous chapters, heavier rains which can be caused by extra warm and wet air, might result in dangerous storms or flooding. (Fecht, 2019)

4.1.1 The Cost of Water Scarcity

Significant changes in water quality and quantity are already evident across the country. According to an estimation by Michigan State University study, 1.6 million U.S. citizens don't currently have regular access to safe drinking water. The same study found out, that almost 50 million households in the country might not be able to afford water or wastewater services next year (2022), due to climate change, aging infrastructure and other factors. According to a Harvard University research, almost half of the 204 fresh water basins in the United States will be unable to fulfill their monthly water demand by 2071. This is due to a combination of causes, including rising population and the impacts of climate change. (Fecht, 2019)

Climate and hydrologic changes affect directly water quality. Warming water temperatures are predicted in all states in the future. Temperature influences the health

of the ecosystem, as well as locally variable increases in precipitation and runoff, affecting pollutant transport into and inside water bodies. These changes present problems in terms of water treatment costs and impacts, and in addition they are posing a risk to water supplies, aquatic ecosystems, human health. (U.S. Global Change Research Program, 2018)

According to National Geographic, almost 165 million U.S. citizens rely on groundwater for drinking water. Around 37% of the country's total water usage is currently used in agriculture. The demand is set to increase, while the supply decreases. The decreasing supply is raising water prices rapidly. This directly affect U.S. households, businesses, and farmers. (Heggie, 2020) For 14 million families, 12% of U.S. households, water bills are already too expensive. Many more Americans are at risk of not being able to afford their monthly water bill as the cost of water increases. According to a 2017 study by Michigan State University scientists, water prices would have to rise by 41% by 2022 to offset the costs of replacing outdated water systems and adjusting to climate change. As an example in the city of Detroit, over 50,000 families have lost the access to water after 2014 because they couldn't pay their bills. (Frostenson, 2018) Water scarcity and expensive water prices affect agriculture directly. Lack of water will lead to higher food prices or event to a shortage of food.

4.2 Agriculture, Forestry and Fishery

Agriculture, forestry, and fisheries are all industries vulnerable to climate change in the United States. These sectors contribute noticeably to the economy, and they provide millions of jobs to Americans. Many regions of the country have already been experiencing climate-related disruptions regularly and more frequently. The effects of climate change can be directly seen in consumer prices of food and timber products.

4.2.1 Agriculture

In 2019, agriculture, food and related industries contributed \$1.109 trillion to the United States GDP, over a five percent share. Over 22 million U.S. jobs were related to the industry, which means that almost 11 percent of the country's employment is provided

by agriculture. During the same year, there were 2.02 million U.S. farms. Majority of these farms are small, but most of the country's production is on large farms. Corn and soybeans accounted for more than 40% of all crop cash receipts in the United States in 2019. Cattle sales accounted for the majority of animal product receipts, followed by dairy products. (USDA, 2021) As can be seen from these numbers, agriculture plays an important role in contributing to country's economy.

Many regions in the United States are experiencing climate-related disruptions regularly and more frequently. While certain areas of the country and some forms of agricultural productions are less vulnerable to climate change, the whole industry will gradually suffer due to increased downpours, extreme heat, drought, and disease. These events can have devastating impacts on crops and livestock across the country. (U.S. Global Change Research Program, 2014)

In the future, effects of the climate change will impact food security in the United States. Changes in crop yields and food costs, as well as impacts on food production, packaging, distribution, and retailing, will also be seen in the whole country. (U.S. Global Change Research Program, 2014) Increasing food insecurity and food prices can worsen food poverty in the country. People cope by eating nutrient-deficient yet calorie-dense diets or by going hungry, with effects ranging from micronutrient deficiency to obesity. Because of increased pest and weed growth, as well as decreasing effectiveness and durability of certain chemicals, farmers are expected to use more pesticides and herbicides. Farmers, farmworkers, and customers would be exposed to these chemicals and their hazardous residues at a growing pace. (CDC, 2019) Human health will be affected in a number of ways, and costs can be high. As mentioned earlier, over 22 million U.S. jobs are related to agriculture and most of these jobs are performed outside. Increased number of natural disasters and especially extreme heat will affect farmworkers in the future. There is a price for days missed work, both for employees and employers.

4.2.2 Forestry

The United States has the world's fourth largest forest estate, accounting for around 8% of the world's forest land. The U.S. has approximately 304 million hectares of forest

land, which covers about a third of the country's overall land area. The majority of forests in the United States are in the eastern half of the country, where private ownership accounts for 83% of forest land. The federal government has no official authority over private forest property in the United States. Private possession accounts for 56% of the country's forest lands. State, territorial, provincial, and federal governments are in charge of the rest. (Tidwell, 2016) The forest products industry in the United States is thriving, providing a significant amount of jobs, revenue, manufacturing sales, and value added to rural forest economies across the nation. Overall, timber goods account for about 1.5% of the US economy and contribute about 5% of the country's manufacturing production. The U.S. is the world's leading user and manufacturer of forest products, accounting for approximately 30% of global forest products in all major categories. (Alvarez, 2019)

The forest industry in the United States is already facing many difficulties related to climate change. Increasing number of wildfires, drought, precipitation pattern changes, and outbreaks of insects and diseases are threatening the industry. Forest product losses caused by these events are already causing massive financial losses. According to one study, in the North American timber market, annual producer welfare damages from climate change are expected to range from \$1.4 to \$2.1 billion a year on average over the next century, with an elevated figure arising from probable extensive dieback. (Sedjo and Sohngen, 2005)

4.2.3 Fishery

Commercial and recreational fishing are a major business in the United States, that supports a significant number of jobs. U.S. commercial fisheries and the seafood industry is worth 5.6 billion dollars. (NOAA Fisheries, 2020) In 2016, at the national level, the commercial fishing and seafood

30 industries in the United States generated \$212 billion in revenue, added \$100 billion to GDP, and provided 1.7 million full- and part-time jobs in fishing and the wider economy. (NOAA Fisheries, 2018) Highest value species groups in the U.S. are lobster (\$684MM), crabs (\$645MM), salmon (\$598MM), scallops (\$541MM) and shrimp (\$496MM). Aquaculture production in the U.S. is worth 1.5 billion dollars including oysters, clams, salmon, mussels, and shrimp. (NOAA Fisheries, 2020)

Climate change effects on the environment have also already impacted fisheries, according to scientific research. While the number of cold-water species is decreasing, several tropical species are emerging along U.S. coastlines. Warming and acidification of the oceans and lakes will impact the development and reproductive cycles of many aquatic creatures in the coming decades, potentially reducing the stocks available for many commercially important species. For example, shellfish such as oysters and mussels are particularly vulnerable to acidification. Furthermore, including their importance for small island economies and human nutrition, almost all coral reefs in tropical areas are likely to vanish by 2050. (Ocean & Climate Platform, 2021)

If climate change continues to progress, the commercial fishing and seafood industry will suffer financially and thousands of people might lose their source of income. Fish and shellfish are also considered to be an important food source. If fish and aquatic creature populations decline, the prices of seafood will go up.

4.3 Human Health

According to the Centers for Disease Control and Prevention, climate change, along with other natural and man-made health stressors, has a wide range of effects on human health and illness. Current health threats will become more serious, and new health threats will arise in the future. Increased respiratory and cardiovascular diseases, accidents and premature deaths associated with weather disasters, variations in the prevalence and geographic spread of infectious diseases, and threats to mental health can be serious consequences of climate change. Not everyone is at risk in the same way. Age, financial capital, and location are important factors to remember. (CDC, 2019)

In some regions, climate change is expected to endanger human health by increasing ground-level ozone and particulate matter air emissions. Reduced lung function, elevated hospital admissions and emergency department visits for asthma, and a rise in premature deaths can be often associated with ground-level ozone. Based on a US assessment of health impacts from ozone levels in the early 2000s, health-related costs of existing effects of ozone air pollution above national standards have been estimated at \$6.5 billion. By 2050, cumulative ozone and particle health impacts are estimated to

cause 1,000 to 4,300 additional premature deaths in the United States. (CDC, 2019) The increasing number of wildfires and exposure to wildfire smoke is also contributing to respiratory and cardiovascular hospitalisations.

Climate is one of the variables that affects the distribution of diseases transmitted by vectors including fleas, ticks, and mosquitoes, which spread pathogens that can cause illness. Climate variability can lead to vector/pathogen adaptation or geographic range changes and expansions. Seasonal variations, air and water temperatures, as well as precipitation patterns are also known to affect food and waterborne diarrheal disease transmissions. Diarrhea disease is a significant public health concern in developing nations, and although it is not currently on the rise in the U.S., it is a persistent concern. These diseases are more common when temperatures get higher. Diarrheal illnesses have also been shown to be more common when precipitation levels are exceptionally high or low. (CDC, 2019)

In the United States, mental illness is one of the primary causes of suffering, and extreme weather events may have a range of impacts on mental health. Mental health issues rise in the aftermath of crises, among both those without a history of mental illness and those at risk. The symptoms can be short-lived or long-lasting. For example, after Hurricane Katrina, studies revealed elevated levels of anxiety and post-traumatic stress disorder in those affected, and similar findings have been made after floods and heat waves. Furthermore, some patients with psychiatric illnesses are particularly vulnerable to heat. Suicide rates fluctuate with the weather, increasing with high temperatures, implying that climate change can have an effect on depression and other mental illnesses. During heat waves, dementia is a risk factor for hospitalisation and death. (CDC, 2019)

It is important but very challenging to calculate the cost of climate change on human wellbeing. Climate change related health impacts are common, severe, and expensive, but they are often ignored in policy discussions and studies. These effects should be tracked and monitored more carefully in the future, in order to get a more clear picture of the consequences and true costs. As we can see from the previous chapters, the price tag of health-related costs is often significant even during individual climate related events. Many health related costs are associated with extreme weather events. Other threats such as increased respiratory problems, diseases, consequences of food

poverty, and climate event-related mental illnesses often get ignored, even though the costs of these threats are tremendous for individuals, the whole nation, and the economy.

4.4 Tourism

Many countries that are vulnerable to climate change, including United States, are considered to be tourism hotspots. Tourism is a major economic sector in the United States and almost 80 million tourists visit the country yearly. In 2017, the industry generated over 1.6 trillion dollars in economic output, supporting 7.8 million jobs. During the same year, travel and tourism exports accounted for 11% of all United States exports and 32% of all service exports. Travel and tourism in the United States accounted for 2.8 percent of the country's gross domestic product. In 2017, overseas travellers spent \$251 billion in the United States, resulting in a \$77 billion trade surplus for the year. (Select USA, 2017)

Coastal cities and mountain regions are most likely to suffer from the consequences of changing climate. Higher sea levels, beach erosion, greater harm from storms and sea surges, and reduced water supply will affect seaside tourism negatively. As the climate gets warmer, the winter seasons will shorten. In mountain regions, it is very likely that in the future the demand for winter sports will eventually diminish. (World Tourism Organization, 2003) Increasing climate disasters such as hurricanes and forest fires are also impacting tourism. Travelling is often temporarily suspended to regions that have been impacted by a severe natural disaster.

4.5 Who Pays for Climate Change?

So who is actually paying for the consequences of climate change? In 2012, taxpayers in the United States spent three times what private insurers did to cover the losses caused by extreme weather. During the same year, more taxpayer money was spent by the federal government on the consequences of severe weather than for example on education or transportation. (Lashof and Stevenson, 2013)

The impacts of climate change have cost the U.S. government billions of dollars, and these costs are projected to continue to increase in the future. According to a report released by the Government Accountability Office, climate change has already cost American taxpayers more than \$350 billion over the past decade. This figure will rise to \$35 billion a year by 2050. Clean-up and emergency relief from hurricanes and floods are included in the costs, which are expected to rise as temperatures rise. (GAO, 2017) Consistent and high costs of extreme weather are also threatening to make insurances too expensive for most Americans. In the future insurance companies might have to raise their premiums in order to remain profitable.

Climate change's negative impacts are projected to continue to be a burden on the U.S. gross domestic product. In 2015, a Stanford research attempted to predict the effect of climate change on GDP, concluding that there was a greater than 50% likelihood that climate change would decrease the United States' GDP by 28%. (Stanford University, 2015)

Climate change will most likely create mass migration in the U.S. and around the world. People will have to flee flooding coastlines, areas of natural disasters and drought-stricken land. As climate change worsens conditions in Latin America, immigration at the southern US border is likely to rise. According to the World Bank, by 2050, between 1.4 million and 2.1 million inhabitants in Mexico and Central America will be forced to relocate due to climate change. (Rigaud et al., 2018)

Climate change will affect each individual in the United States, some people will suffer more than others. Increasing amount of climate disasters will continue to destroy many homes, businesses, and human health. Every taxpayers in the United States will be paying for the damage.

5 Future of Climate Change

What will the U.S look twenty years from now? Global carbon emissions continue to increase, and devastating storms, wildfires, and rising seas have become daily news. Whatever changes or happens in the coming decades, scientists are almost certain that

global temperatures will continue to increase, as glaciers will melt and sea levels rise. The impact of climate change on particular regions will vary with time. The quantity of heat-trapping gases released worldwide and how vulnerable the earth's atmosphere is to those emissions determine the extent of climate change beyond the next few decades.

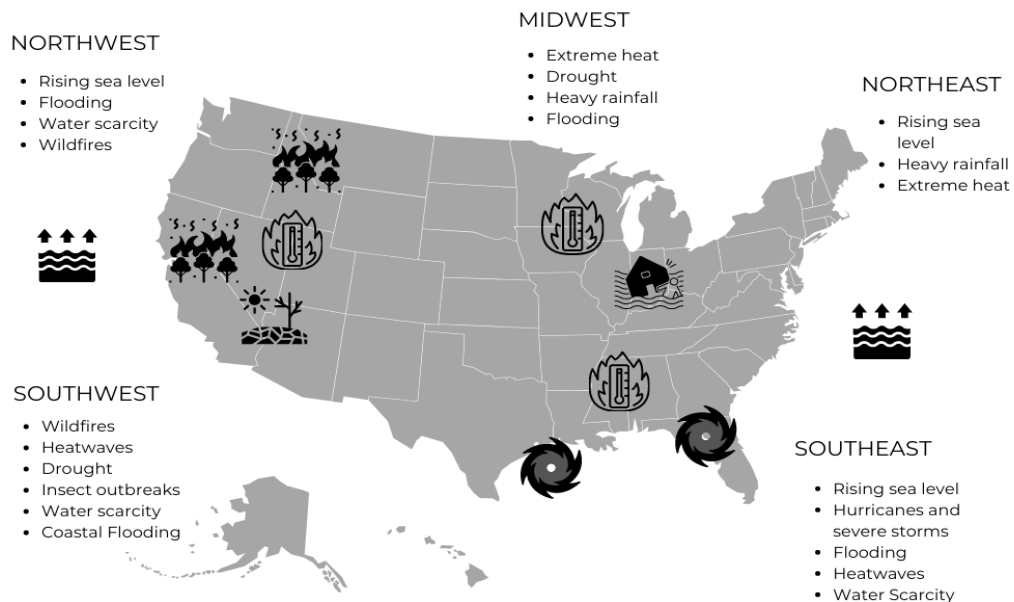


Figure 4: Future of Climate Change (Data Source: NASA, 2018)

Figure 4 shows climate events that are posing major threats to different regions of the United States. In Northwest, rising sea level, increasing ocean acidity, erosion, and flooding are posing major threats to the region. Changes in streamflow timing is also decreasing water supplies required to satisfy competitive demands. The qualifying number of wildfires, pest outbreaks, and tree diseases will cause a widespread tree loss. (NASA, 2018)

In the Northeast, many aspects of life will be challenged by heat waves, heavy rainfall and rising sea level. Ecosystems, infrastructure, agriculture, and fisheries will become increasingly compromised. Climate change is starting to be incorporated into the plans of several states and towns in the region. (NASA, 2018)

Midwest will be suffering from extreme heat, heavy rainfall, and flooding, which will affect agriculture, forestry, water quality, health, as well as infrastructure. A variety of threats to the Great Lakes will be intensified as a result of climate change. (NASA, 2018)

In Southwest, wildfires have already intensified as a result of increased heat, drought, and insect outbreaks, all of which are related to climate change. Additional issues that the region will be facing in the future include diminishing water supplies, lower crop productivity, heat-related health effects in cities, and coastal flooding and erosion. (NASA, 2018)

The climate and economy of Southeast U.S. are threatened by rising sea levels. More frequent heat waves in the region will affect agriculture, energy, health and more. Additionally, intensifying and more frequent hurricanes and storms will be causing a lot of damage. Water scarcity that is threatening Southeast will have severe economic and environmental consequences. (NASA, 2018)

In addition to the impacts listed above and seen in the figure 4, climate change will be causing severe and expensive health impacts around the nation. Furthermore country's tourism sector will suffer financial losses. Coastal cities and the tourism in Northeast, Northwest, Southeast, and Southwest will be most affected in the future.

5.1 Has Anything Changed?

As already mentioned in the beginning of this paper, United States is the world's second biggest polluter after China and the country just had a president who denied the facts of climate change. The question is, has anything actually been done in the country in order to stop the climate change?

In 2020, researchers from Yale University studied how Americans' climate change beliefs, policy support and risk perceptions vary. According to the study, 72% of the U.S. adults believe that global warming is happening and 57% believe that global warming is caused by human activities. 63% of American people were worried about global warming and 71% thought that it will harm future generations. Most of the Americans were

supportive towards climate policies in the country. 61% thought that global warming will harm people in the U.S., but only 43% of the people believed, that global warming would harm them personally. (Marlon et al., 2020) There is still a lot room for improvement, when it comes to people's attitudes and behaviour towards protecting the planet and the country.

According to some sources, United States has taken some steps towards more sustainable future. The country has established ambitious goals to reach greenhouse gas emissions, signed legislation that ramps up renewable energy, pushed for better energy efficiency, accelerated zero-emission vehicle programs, regulations to reduce toxic air pollutants have been proposed, new financing opportunities have been created for clean energy, and special tools and resources have been developed to help the states address climate change. (Green, 2019) The current U.S. president Joe Biden has been placing a lot of emphasis on climate change and one of the first things he did as the new president in the beginning of 2021, was to rejoin the Paris climate agreement. Many promises have been made, but words need to be matched with deeds. A lot of times when you look behind these targets and plans to reduce emissions, there is not unfortunately a lot of substance behind the commitments.

6 Conclusion

Climate change is a serious global problem. The climate change and global warming we are experiencing right now, are caused by the excessive amount of greenhouse gas emissions entering the earth's atmosphere. United States is the world's second biggest polluter after China, and energy, agriculture, industrial processes, and waste are some of the industries and activities that are heavily contributing to the problem. Climate change or global warming doesn't just harm the environment, it will also cost a lot of money. As a whole, the range of published evidence and this report indicates that the cost of climate change in the United States is already significant and it will most likely continue to increase in the future.

In the United States, extreme weather events have already become more frequent and severe, and country's citizens, businesses, and infrastructure are suffering from the consequences. Tropical cyclones are the most costly climate disaster event in the United States, followed by drought, wildfires, and flooding. United States has experienced 285 billion-dollar climate disaster, and almost 18% of them have occurred during the last three years. Most of the time, only direct costs of these events including property losses, fatalities, lost local business revenues, and infrastructure damages are documented. Indirect costs such as property value losses, or addition costs including rehabilitation and healthcare costs are overlooked. Some regions and states in the country such as Texas and Florida are more prone to these extreme weather events.

Increasing extreme weather events are not the only problem disrupting the U.S. economy. Water quantity and quality, agriculture, forestry and fisheries, human health, and tourism are all affected by the climate change and global warming. Significant changes in water quality and quantity are already evident across the country. Decreasing supply is raising water prices rapidly, which directly affects U.S. households, businesses, and farmers. Agriculture, forestry, and fisheries all contribute noticeably to the U.S. economy, and they provide millions of jobs to Americans. Since many regions of the country have already been experiencing climate-related disruptions, the effects of climate change can be directly seen for example in consumer prices of food and timber products.

Climate change has a wide range of effects on human health as well. These related health impacts are common, severe, and expensive, but still they are often ignored in policy discussions and studies. Because of climate change, current health threats will become more serious, and new threats will arise in the future. Climate change will also affect tourism, which is a major economic sector in the United States. Coastal cities and mountain regions are most likely to suffer from the consequences of changing climate and pay the highest price.

The true economic costs of climate change in the United States are uncertain. Only thing that is determined, is that the federal government, companies, and U.S. taxpayers will be paying for it. Regardless of what changes or happens in the future, unfortunately global temperatures will most likely continue to rise and problems related to climate

change will quantify all over the world. This still doesn't mean that the problem should be ignored, terrible effects can still be minimised. Measures that will help to adapt to these impacts and changes incur costs, but the benefits will outweigh the costs of inaction in the long run.

So what has to be done in order to stop or at least slow down global warming? Nearly three-quarters of global emissions originate from the energy sector. (Ritchie and Roser, 2020) The single most crucial thing we can do to fight climate change, is to limit the use of fossil fuels and replace them with clean and renewable energy. According to the 2017 CDP Carbon Majors Report, 25 corporations and state-owned enterprises are responsible for over half of the total industrial green house gas emissions. The study also states, that solely 100 companies are responsible for 71% of global industrial emissions. (Griffin, 2017) These companies need to do better and start taking measures against climate change. Additionally, new policies and laws need to be implemented globally to force corporations to reduce their energy consumption and waste.

Overconsumption and overproduction are major reasons behind all emissions. High demand of consumer goods drives the production. As a society we need to change our habits and start promoting more sustainable lifestyle. Consumers need to start investing in renewable and clean energy, reduce waste, and eat less animal-based products. Agriculture, forestry, and land use account for almost 20% of global greenhouse gas emissions. (Ritchie and Roser, 2020) Meat, dairy, and other animal-based products have a higher carbon footprint. According to an Oxford University study, veganism could be the most powerful way to reduce individual's environmental impact. The same study discovered, that if everyone avoided consuming animal products, global agricultural consumption could be cut by 75%. (Poore and Nemecek, 2018)

Collaboration between public and private sector is needed in order to take urgent measures as soon as possible. Companies need to be held accountable for their emissions, and people need to be educated. We already have the solution, it just needs to be acted on.

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