Climate & Sleep

Amanda Anderson-You

M.S. Data Visualization Candidate, Parsons School of Design

Submitted in partial fulfillment of the requirements for the degree of Master Science in Data Visualization at Parsons School of Design.

Thesis Faculty:
Daniel Sauter
Aaron Hill

May 2020

TABLE OF CONTENTS

Abstract 3

Introduction 4

Treatment

Climate Crisis Overview 5

Sleep Health Overview 6
The Difference of a Good Night's Sleep Visualization 7

Air Quality 9
Air Quality Across US Regions Visualization 11 & 12

Asthma 13
Insufficient Sleep & Asthma Visualization 15 & 16

Extended Allergen Season 17
Increased Length of Allergen Season Visualization 18

Rising Temperatures 18
Extreme Heat Nights & Vulnerable Communities Visualization 21 & 22

Climate & Mental Health 23

Conclusion 23

Bibliography 25

Appendix 30

ABSTRACT

The thesis project Climate & Sleep focuses on the implications of the climate crisis on one of our most fundamental human needs: sleep. As global heating continues to increase and threaten life as we know it, humans are required to evaluate how these changes are impacting their daily lives and adapt accordingly. The Centers for Disease Control and Prevention (CDC) states that adults between the ages of 18 and 60 are recommended to sleep for 7 hours or more a night.[1] Not only is this amount of sleep important, but the quality of one's sleep is also critical. This thesis evaluates how poor air quality and rising temperatures, factors of the climate crisis, relate to sleep health in America. Inspired by Rifkin et al.'s systematic review[2] of the literature and conceptual framework on this topic, I have chosen to research and visualize the relationships between sleep health and the climate crisis by focusing on air quality changes and rising temperatures. I will be utilizing data from United States government agencies such as the CDC, the National Centers for Environmental Information (NCEI) and the Environmental Protection Agency (EPA) in order to explore the most recent as well as historical data. This project aims to increase understanding of current climate circumstances to improve social well-being. I aim to provide visualizations to the community of people who are working in the fields of climate crisis or sleep health. The climate crisis is inevitable, and the more we are aware of its impacts on our basic needs, the more adaptable we can become.

[1] Hirshkowitz, 2015

[2] Rifkin, 2018

INTRODUCTION

Climate & Sleep proposes to visualize the dynamic relationship between resulting factors of global heating and the threatening effects they have on Americans' quality of sleep. At this time in our history, we are faced with decisions and policies to attempt to mitigate the extreme consequences of global heating and adjust or eliminate the behaviors that have brought us to this point. There are many factors to consider when discussing the climate crisis, and arguably more immediate and obvious pressing issues to focus on than sleep. However, sleep is also a critical topic and essential for human health. A third of US adults report that they sleep less than the recommended 7 hours. The CDC declares insufficient sleep to be a public health epidemic. Lack of sleep is linked to chronic diseases and conditions such as diabetes, heart disease, obesity, and depression.[3]

To evaluate the connections between the climate crisis and sleep health, I am choosing to focus on specific effects of global heating and evaluate how they perpetuate or emphasize insufficient sleep. While poor sleep health is tied to many health implications, I have chosen to not attempt to broaden and fully encompass all elements of either the climate crisis or sleep health in order to dive deeper into select relationships. The overarching structure around this thesis is inspired by "Climate change and sleep: A systematic review of the literature and conceptual framework" a journal article completed by Rifkin et al. Their framework also investigates the areas of rising temperature's impact on sleep and the relationship of human sleep to extreme weather events and climate related disasters.[2] Another inspiration for the content of this thesis includes a systematic review by Tenero et al. exploring the impact of air pollution on sleep related breathing disorders.[4] My thesis is focusing on human sleep only, and will use data from the United States. I hope that a greater understanding of the threats the climate crisis imposes on sleep health will lead to increased mitigation efforts and increased attention paid to helping the communities that are the most vulnerable.

When we evaluate the implications of the climate crisis, the vulnerability of sleep quality is a factor that is perhaps not widely considered. The purpose of this thesis is to look more in depth into select relationships between results of the climate crisis and their contributions to deterioration of sleep health. I plan to utilize the systematic reviews referenced previously to guide my research and review recent material that has been published since those reviews were created. The CDC, EPA, and NCEI all provide ample

[3] Hafner, 2017

[4] Tenero, 2017

reports and data surrounding the complex topics of climate and sleep. I will utilize this information to gain not only current records but also report on the historical context and future projections on the concepts as well. The health implications of poor air quality and rising temperatures as they relate to sleep will serve as the focus of this project. I will go into further detail on the relationships of climate and sleep for each subsection to demonstrate how the climate crisis is impacting sleep.

CLIMATE CRISIS OVERVIEW

Encyclopedia Britannica defines global warming as "the phenomenon of increasing average air temperatures near the surface of Earth over the past one to two centuries." [5] The climate crisis is changing the way we live, in big and small ways. According to the 2018 Fourth National Climate Assessment (NCA) assessing the science of climate change and its impacts across the United States throughout the last century, climate change not only creates new risks, it also builds upon and makes visible, existing vulnerabilities within communities across the country. These risks and vulnerabilities continue to grow and impact human health, safety, quality of life, and economic growth.[6] Among these changes are more frequent and intense extreme weather and changes in average climate conditions such as rising temperatures. Figure 1 in the reference section of this paper displays a visual communicating the relationship between elements of climate change such as increased temperatures, to an impact on our environment like poor air quality, and ultimately to the health outcomes such as mental health consequences and stress. This flow is useful in conceptualizing climate drivers and how their exposure pathways impact health outcomes.[7]

According to the Intergovernmental Panel on Climate Change (IPCC) formed in 1988 by the World Meteorological Organization and the United Nations Environment Program, global heating continues to increase, and it is forecasted that the global mean surface temperature will rise between 3 and 4 degrees Celsius by 2100 if the existing rate of carbon emissions persists. The impacts of this temperature increase will be dramatic and will contribute greatly to the perpetuation of degradation in air quality, the rising of temperatures, and extreme weather events all adding to loss of quality sleep.

[5] Encyclopedia Britannica
[6] NCA, 2018
[7] Balbus, 2016

The climate crisis is not equally distributed. Those who are vulnerable based on income level, elderly age, or preexisting conditions will experience greater impacts due to deteriorating infrastructure, stressed ecosystems, and economic inequality.[7] It is vital to prioritize adaptation actions across the United States. Extreme weather and climate-related changes will increase risks across critical systems such as water, food production, distribution, energy, transportation, public health, trade, and national security. These interconnected systems are all impacted and increased mitigation of these risks relating to climate change will lead to more effective management and responses. One of these risks, public health, includes assessing the impact of global heating on human sleep quality.

SLEEP HEALTH OVERVIEW

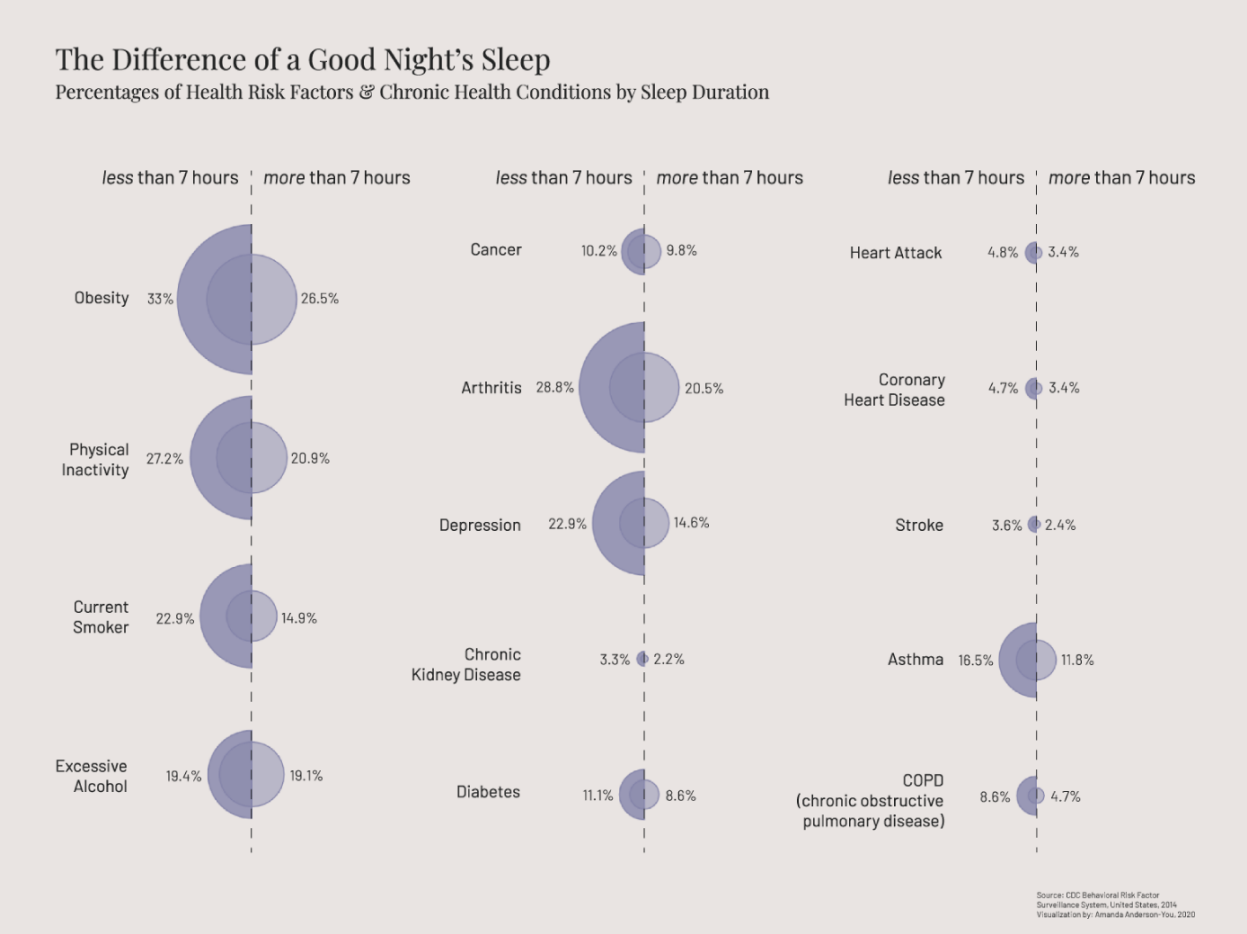
About 50 to 70 million Americans have sleep disorders.[8] There are many health risk factors associated with sleeping less than the recommended amount of 7 hours regularly, including obesity, diabetes, heart disease, depression, and more. Sleeping is a basic human need; healthy sleep necessitates sufficient duration, quality, timing, and regularity with the absence of sleep disturbances or disorders.[8] Your body has an internal clock called the circadian rhythm that has a cycle of approximately 24 hours controlling when you are awake and when you're ready for sleep. Your circadian rhythm affects every cell, tissue, and organ you have and how they operate. It is regulated by factors including light, darkness, and sleep schedules.[8] Sleep health is of high priority because it affects many of your body's systems. For children and teenagers, sleep plays an integral role in supporting growth and development.[8] Timing and duration of sleep impacts endocrine, metabolic, and neurological functions that are critical to the preservation of one's health.[9] This thesis paper explores how climate change impacts sleep health through the exposure pathways of poor air quality and rising temperatures.

One of the visualizations in my thesis project focuses specifically on the health risk factors and chronic health conditions that a person is more likely to experience if they regularly sleep an insufficient amount. The data was collected from the CDC's Behavioral Risk Factor Surveillance System report conducted in 2014 and loaded into p5.js through a created CSV file. In all of the examples, the percentages for one of these risks or

[8] NHLBI, 2020

[9] Healthy People 2020

conditions is higher with less than seven hours of sleep. In order to allow the viewer to easily compare and contrast, I chose to represent each factor with circular shapes, meeting in the middle to show the size difference of the percentages. This design lets the highest percentages stand out, while not hiding the smaller examples or making them difficult to read. We can ascertain that many of these conditions are not exclusive to sleep, and that the feedback loop between them is likely cyclical. For example, those who are physically inactive and drinking excessively, also may be depressed and not sleeping well.



The Difference of a Good Night's Sleep: Visualization from Climate & Sleep Thesis Project

When you are asleep, you breathe less often, less deeply, and absorb less oxygen. For people who suffer from asthma, these changes can be a problem with symptoms worsening typically during early morning sleep. Asthma is a chronic condition affecting people of all ages that intermittently inflames and restricts the airways in the lungs making

the airways swell. Common reactions include a range of mild to severe wheezing, chest tightness, shortness of breath and coughing.[8] Researchers do not know the exact cause of asthma; however, it is typically the result of an immune system response to allergens in the environment. Global heating impacts allergens as it prolongs and enhances pollen production.[9] The increase of air pollutants including ozone and particulate matter further irritates the respiratory systems of people with asthma.

Obstructive sleep apnea (OSA) is described as sleep disordered breathing characterized by intermittent upper airway obstruction or pauses in breathing for 10 seconds or longer.[9] This pause in breathing cuts off the oxygen supply to your body, and also impedes the removal of carbon dioxide. Your brain wakes briefly to re-open the airways and re-start breathing.[10] For those with severe sleep apnea, this cycle happens over 30 times in an hour.[8] According to the National Heart, Lung, and Blood Institute, sleep apnea is dangerous not only because it is linked to adverse daytime consequences such as poor performance and accidents, but it also can result in neurocognitive and cardiovascular consequences, heart disease, insulin resistance, stroke, and hypertension. Sleep apnea can be caused by a person's physical build or by medical conditions.[11]

Insomnia is the most commonly reported sleep disorder.[12] It is also typically diagnosed alongside other mental health illnesses such as depression and post-traumatic stress disorder. According to the Institute of Medicine, "Insomnia is defined by difficulty falling asleep, maintaining sleep, or by short sleep duration despite adequate opportunity for a full night's sleep." The causes of insomnia aren't clear; however, they are generally considered to involve a combination of biological, psychological, and social factors with stress playing a role in chronic insomnia.[13] Other factors contributing to insomnia include light exposure, and inconsistent sleep schedules.[13] Stress related to extreme weather events or high temperatures impacting sleep schedules is the connecting link between the climate crisis and its impact on sleep health.

There are many consequences of global heating that have the potential to impact sleep health. Utilizing the previous sections outlining a brief, general overview of the climate crisis and sleep health, this thesis will move forward to center further on the direct relationships between air quality and rising temperatures and relating sleep health risks to

[10] WHO: OSA, 2011
[11] Williams, 2007
[12] Ohayon, 2002
[13] Institute of Medicine, 2006

understand the relationships between the specified exposure pathways and their sleep health outcomes.

AIR QUALITY

Air pollution is the result of the release of harmful or excessive quantities of gaseous substances such as nitrogen dioxide, ozone, and particulate matter (PM) into the atmosphere.[14] According to the 2018 National Climate Assessment, more than 100 million people in the USA reside where air pollution exceeds health-based air quality standards. The World Health Organization reported in 2018 that 9 out of 10 people worldwide breathe polluted air, and an estimated 7 million people die every year due to exposure to fine particles in polluted air that lead to many diseases such as stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases and respiratory infections, including pneumonia.[15] Air pollution causes upper airway irritation that can interrupt your sleep. The climate crisis will continue to worsen these existing air pollution levels especially if restrictions are not maintained or improved.

There are various key pollutants that the EPA tracks that impact the human respiratory system including ground level ozone, particulate matter 2.5, particulate matter 10, sulfur dioxide, and nitrogen dioxide. Ozone is created by a chemical reaction between oxides from nitrogen and volatile organic compounds (VOCs). This event occurs when pollutants from cars, power plants, industrial boilers, refineries, chemical plants etc. react in the company of sunlight. Ozone at the ground level can activate a number of health issues, mainly for children, elderly, and for those with lung diseases like asthma.[16] Atmospheric warming associated with the climate crisis is likely to increase ground level ozone in many regions.[17]

Particulate matter is another pollutant that is especially harmful to those who have respiratory issues as they can be inhaled deep into your lungs and may even enter your bloodstream. There are two types of particulate matter, PM2.5 and PM10. PM10 is made up of inhalable particles that have diameters around 10 micrometers and smaller, particles like dust, pollen, and mold. PM2.5 is made up of finer inhalable particles with diameters

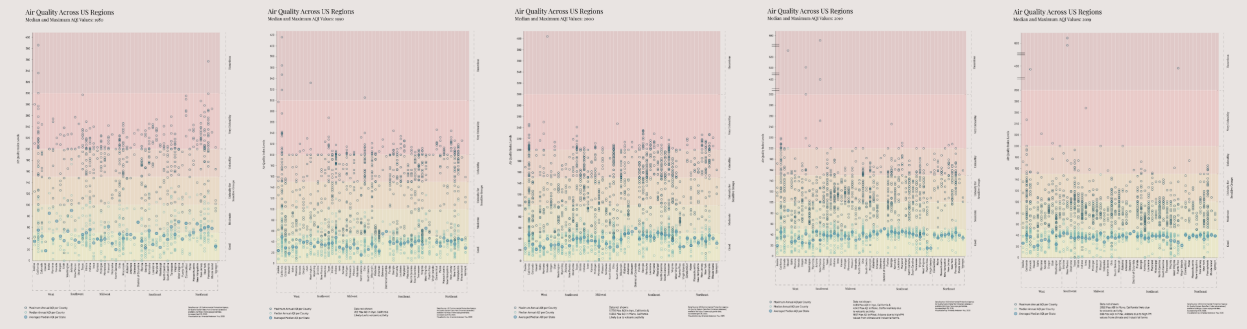
[14] Mutlu, 2019
[15] WHO, 2018
[16] EPA: Ozone, 2018
[17] EPA: Climate Research, 2020

about 2.5 micrometers and smaller like combustion particles, or organic compounds. PM2.5 pose a greater risk to health. Most particles form from complex chemical reactions in the atmosphere between compounds such as sulfur dioxide and nitrogen oxides that come from power plants, industries, and vehicles.[18]

Sulfur dioxide is another tracked pollutant that can harm the human respiratory system. It comes it the form of a gas from the burning of fossil fuels by industrial facilities, power plants, trains, ships, and even from natural sources like volcanoes. Being exposed to sulfur dioxide can make it difficult to breath, especially for people with asthma. Sulfuric oxides can contribute to concentrations of particulate matter when they react in the atmosphere to form small particles.[19] Lastly, nitrogen dioxide pollutants are also a respiratory health concern. Nitrogen dioxide is emitted into the air from burning fuel, typically from cars, trucks, buses, and powerplants. Breathing air with high levels of nitrogen dioxide can irritate your airways causing coughing, wheezing, or difficulty breathing, especially for those with respiratory diseases like asthma or for vulnerable age groups including children and the elderly. Long term exposure may contribute to the development of respiratory conditions. Nitrogen dioxide, like sulfur dioxide, reacts with other chemicals in the atmosphere to form both particulate matter and ozone.[20] Each of these air pollutants damage respiratory systems and can be especially dangerous for those with existing conditions.

In a second visualization I focused on air quality index (AQI) levels to explore the shifts in maximum AQI per county, median AQI per county, and calculated the overall median per state. This is completed five times to cover decades across the time range of EPA data availability from 1980 to 2019. In observing these visualizations, we can see that maximum levels across the country were very high, mostly landing in the unhealthy and very unhealthy ranges between 150 and 300 AQI in 1980. As efforts to manage emissions were required after the 1970 Clean Air Act, maximum levels have gradually declined, with exceptions of occasional dramatically high AQI as a result of volcanic activity, wild and controlled fires, dry, dusty climates, and industrial activity. 1980 sees no reports over 400 AQI, while subsequent visualizations have noted these extreme events sometimes over 10,000 AQI. Monitor location quantity has also increased over time. Overall state median levels also shifted from varying between moderate and good levels in 1980-2010 to all being within the good range of below 50 AQI in 2019.5

[18] EPA: Particulate Matter, 2018
[19] EPA: Sulfur Dioxide, 2019
[20] EPA: Nitrogen Dioxide, 2019can



Air Quality Across US Regions: Visualization from Climate & Sleep Thesis Project

2019 Air Quality: Visualization from Climate & Sleep Thesis Project

Climate change affects air quality in a multitude of ways, whether through excessive periods of drought with dust and high temperatures, increasing wildfire frequency and ground-level ozone pollution, or through shifts in the growing season leading to increased use of fertilizers, pesticides and an extended pollen season with increased pollen production. These factors all worsen respiratory health due to exposure.[8] [9] The frequency and severity of respiratory illnesses such as asthma are expected to increase as a result of the climate crisis.[21] These increases are due to changes in weather which contributes to the concentrations of both ozone and particulate matter in the air, both of which adversely affect human health.

ASTHMA

Asthma is a condition that causes swelling of the airways that carry air from your nose and mouth to your lungs. Asthma can be triggered by allergens or other particles that enter the lungs. There is no cure for asthma, and in some cases it can be deadly. According to the Asthma and Allergy Foundation of America, more Americans have asthma than ever before with it being one of the country's most common and costly diseases.[23] People with asthma frequently endure nighttime coughing, wheezing and breathlessness that interrupts their sleep. Studies examining the role of the circadian rhythm in asthma have been largely inconclusive, however many researchers believe there is a link, especially for "nocturnal asthma" where symptoms are worse at night. At night, your airway resistance increases, especially when you are sleeping. For those without asthma, this change doesn't disturb them. However, for those with asthma, the longer they sleep, the more airway resistance they experience. Airway function is best right before sleep onset and continues to decrease as sleep advances.[22]

Nearly 25 million Americans, or approximately 8% of the population, have asthma. Cases of asthma have been increasing across age, sex, and racial groups since the early 1980s.[23] Asthma affects both children, at 8.4 percent of the population, and adults, at 7.7 percent of the population. Many studies have shown a strong correlation between air pollution and asthma in children. There is accumulative clinical and experimental evidence that connects particulate matter air pollution with asthma, however we do not yet

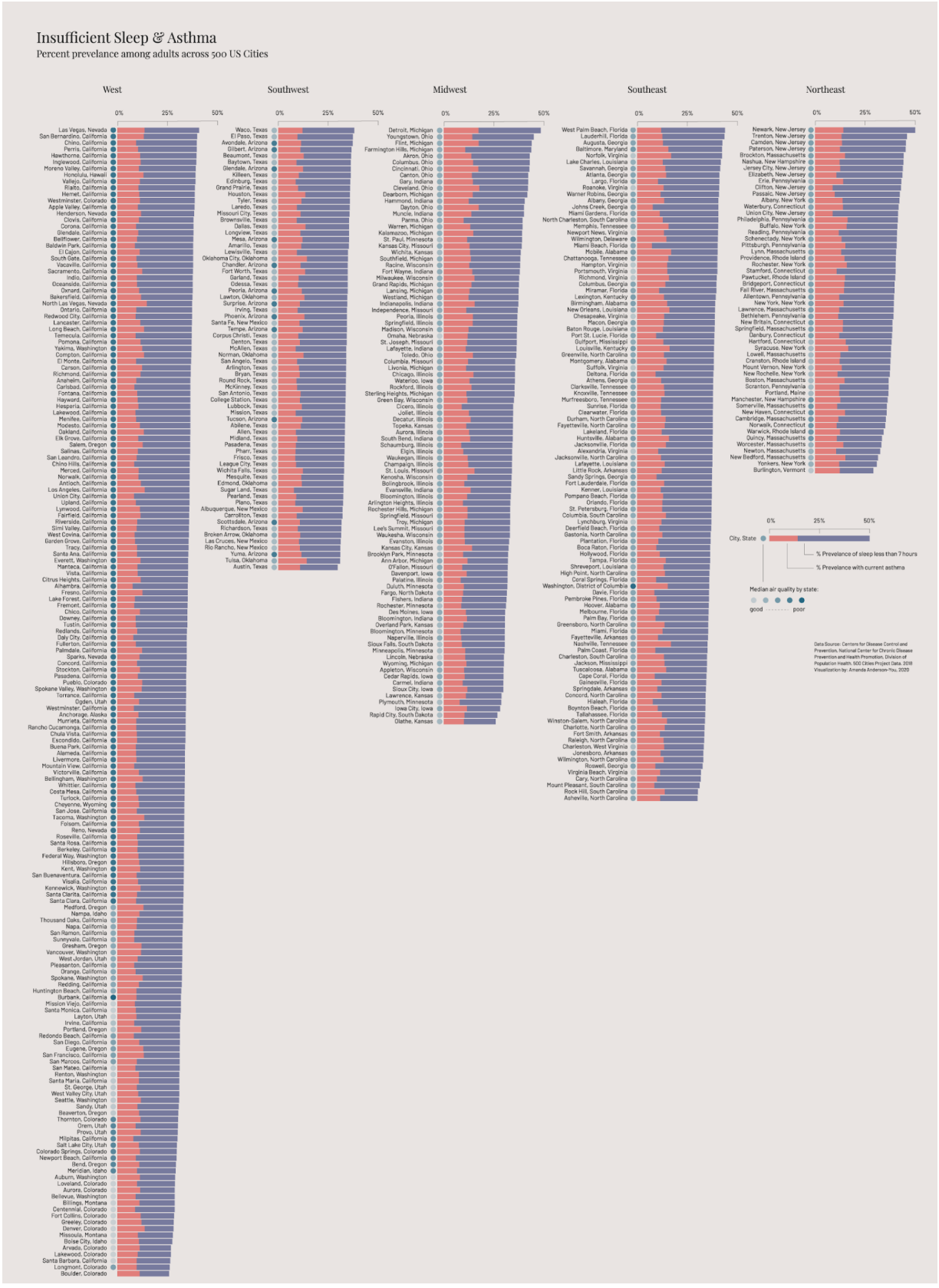
[21] Nolte, 2018
[22] NSF, 2009
[23] AAFA, 2019

understand the mechanisms by which PM affects asthma.[24] In a Systematic review titled *Indoor/Outdoor Non-Voluptuary-Habit Pollution and Sleep-Disordered Breathing in Children*, Tenero et. al examines articles analyzing the relationship between pollution and sleep disorders in children. They find that there is high relevance for the argument, however there is a limited number of studies and interest in the subject at this time.[4]

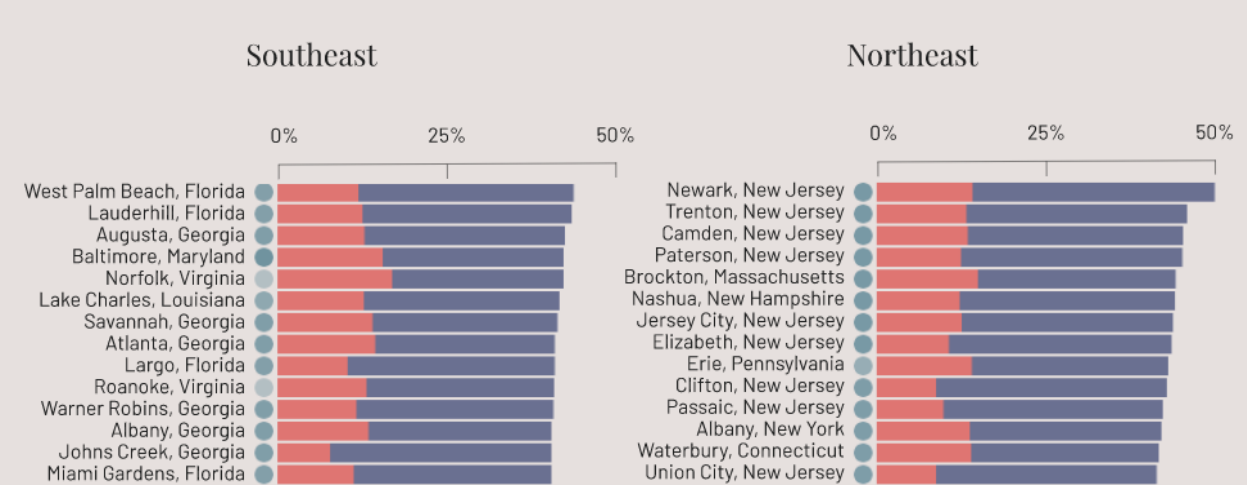
In the third visualization for my thesis project, I compare asthma prevalence and insufficient sleep prevalence across 500 US cities using data from the CDC's 500 Cities: Local Data for Better Health. [25] I also included the state averaged median air quality from 2019 for additional context from the EPA. I worked with the data in CSV format, dividing it into assigned regions, and loading values from each data source. I worked with the P5.js library to create the visualization from the asthma, sleep, and air quality index values. By grouping by region, the user can continue to compare visualizations across the Climate & Sleep project that are also grouped by region. The rows of data within each region are ordered by highest levels of insufficient sleep prevalence to the lowest. For each visualization in this thesis, I used Adobe Illustrator to create and align textual details and generated scalable vector graphic (SVG) files to be displayed on the project website.

In assessing this visualization, we can discern rates of asthma vary throughout the country, however there are lower asthma rates in the Midwest compared to the other regions. The Midwest also has the lowest rate of insufficient sleep by region, while the Southeast and Appalachian Mountain region has the highest prevalence of insufficient sleep. Earlier studies have shown that the Southeast and Appalachian Mountain region also have the highest rates of obesity and other chronic conditions.[26] This area is home to many that are exposed to the repercussions of the coal industry where toxic air pollutants cause respiratory disorders from coal dust as well as heart disease. Toxic runoff into local water sources is also a health concern and burning coal releases carbon dioxide contributing to a warming climate.

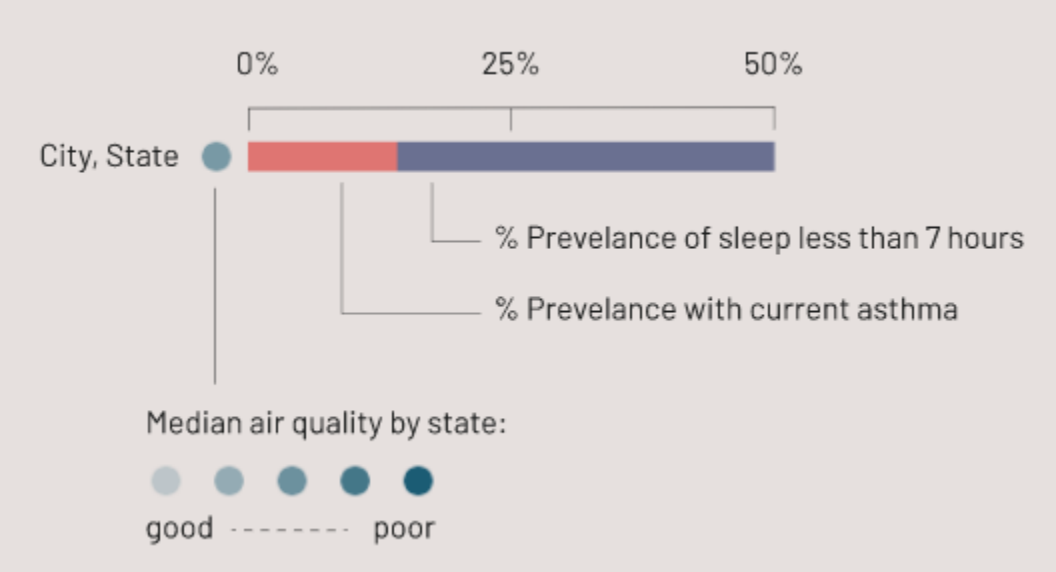
[24] Mutlu, 2019
[25] 500 Cities, 2019
[26] CDC, 2016


Insufficient Sleep & Asthma
Percent prevelance among adults across 500 US Cities
West
Southwest
Midwest
Southeast
Northeast
0%
25%
50%
Las Vegas, Nevada
San Bernardino, California
Chino, California
Perris, California
Hawthorne, California
Inglewood, California
Moreno Valley, California
Honolulu, Hawaii
Vallejo, California
Rialto, California
Hemet, California
Westminster, Colorado
Apple Valley, California
Henderson, Nevada
Clovis, California
Corona, California
Glendale, California
Bellflower, California
Baldwin Park, California
El Cajon, California
South Gate, California
Vacaville, California
Sacramento, California
Indio, California
Oceanside, California
Oxnard, California
Bakersfield, California
North Las Vegas, Nevada
Ontario, California
Redwood City, California
Lancaster, California
Long Beach, California
Temecula, California
Pomona, California
Yakima, Washington
Compton, California
El Monte, California
Carson, California
Richmond, California
Anaheim, California
Carlsbad, California
Fontana, California
Hayward, California
Hesperia, California
Lakewood, California
Menifee, California
Modesto, California
Oakland, California
Elk Grove, California
Salem, Oregon
Salinas, California
San Leandro, California
Chino Hills, California
Merced, California
Norwalk, California
Antioch, California
Los Angeles, California
Union City, California
Upland, California
Lynwood, California
Fairfield, California
Riverside, California
Simi Valley, California
West Covina, California
Garden Grove, California
Tracy, California
Santa Ana, California
Everett, Washington
Manteca, California
Vista, California
Citrus Heights, California
Alhambra, California
Fresno, California
Lake Forest, California
Fremont, California
Chico, California
Downey, California
Tustin, California
Redlands, California
Daly City, California
Fullerton, California
Palmdale, California
Sparks, Nevada
Concord, California
Stockton, California
Pasadena, California
Pueblo, Colorado
Spokane Valley, Washington
Torrance, California
Ogden, Utah
Westminster, California
Anchorage, Alaska
Murrieta, California
Rancho Cucamonga, California
Chula Vista, California
Escondido, California
Buena Park, California
Alameda, California
Livermore, California
Mountain View, California
Victorville, California
Bellingham, Washington
Whittier, California
Costa Mesa, California
Turlock, California
Cheyenne, Wyoming
San Jose, California
Tacoma, Washington
Folsom, California
Reno, Nevada
Roseville, California
Santa Rosa, California
Berkeley, California
Federal Way, Washington
Hillsboro, Oregon
Kent, Washington
San Buenaventura, California
Visalia, California
Kennewick, Washington
Santa Clarita, California
Santa Clara, California
Medford, Oregon
Nampa, Idaho
Thousand Oaks, California
Napa, California
San Ramon, California
Sunnyvale, California
Gresham, Oregon
Vancouver, Washington
West Jordan, Utah
Pleasanton, California
Orange, California
Spokane, Washington
Redding, California
Huntington Beach, California
Burbank, California
Mission Viejo, California
Santa Monica, California
Layton, Utah
Irvine, California
Portland, Oregon
Redondo Beach, California
San Diego, California
Eugene, Oregon
San Francisco, California
San Marcos, California
San Mateo, California
Renton, Washington
Santa Maria, California
St. George, Utah
West Valley City, Utah
Seattle, Washington
Sandy, Utah
Beaverton, Oregon
Thornton, Colorado
Orem, Utah
Provo, Utah
Milpitas, California
Salt Lake City, Utah
Colorado Springs, Colorado
Newport Beach, California
Bend, Oregon
Meridian, Idaho
Auburn, Washington
Loveland, Colorado
Aurora, Colorado
Bellevue, Washington
Billings, Montana
Centennial, Colorado
Fort Collins, Colorado
Greeley, Colorado
Denver, Colorado
Missoula, Montana
Boise City, Idaho
Arvada, Colorado
Lakewood, Colorado
Santa Barbara, California
Longmont, Colorado
Boulder, Colorado
Waco, Texas
El Paso, Texas
Avondale, Arizona
Gilbert, Arizona
Beaumont, Texas
Baytown, Texas
Glendale, Arizona
Killeen, Texas
Edinburg, Texas
Grand Prairie, Texas
Houston, Texas
Tyler, Texas
Laredo, Texas
Missouri City, Texas
Brownsville, Texas
Dallas, Texas
Longview, Texas
Mesa, Arizona
Amarillo, Texas
Lewisville, Texas
Oklahoma City, Oklahoma
Chandler, Arizona
Fort Worth, Texas
Garland, Texas
Odessa, Texas
Peoria, Arizona
Lawton, Oklahoma
Surprise, Arizona
Irving, Texas
Phoenix, Arizona
Santa Fe, New Mexico
Tempe, Arizona
Corpus Christi, Texas
Denton, Texas
McAllen, Texas
Norman, Oklahoma
San Angelo, Texas
Arlington, Texas
Bryan, Texas
Round Rock, Texas
McKinney, Texas
San Antonio, Texas
College Station, Texas
Lubbock, Texas
Mission, Texas
Tucson, Arizona
Abilene, Texas
Allen, Texas
Midland, Texas
Pasadena, Texas
Pharr, Texas
Frisco, Texas
League City, Texas
Wichita Falls, Texas
Mesquite, Texas
Edmond, Oklahoma
Sugar Land, Texas
Pearland, Texas
Plano, Texas
Albuquerque, New Mexico
Carrollton, Texas
Scottsdale, Arizona
Richardson, Texas
Broken Arrow, Oklahoma
Las Cruces, New Mexico
Rio Rancho, New Mexico
Yuma, Arizona
Tulsa, Oklahoma
Austin, Texas
Detroit, Michigan
Youngstown, Ohio
Flint, Michigan
Farmington Hills, Michigan
Akron, Ohio
Columbus, Ohio
Cincinnati, Ohio
Canton, Ohio
Gary, Indiana
Cleveland, Ohio
Dearborn, Michigan
Hammond, Indiana
Dayton, Ohio
Muncie, Indiana
Parma, Ohio
Warren, Michigan
Kalamazoo, Michigan
St. Paul, Minnesota
Kansas City, Missouri
Wichita, Kansas
Southfield, Michigan
Racine, Wisconsin
Fort Wayne, Indiana
Milwaukee, Wisconsin
Grand Rapids, Michigan
Lansing, Michigan
Westland, Michigan
Indianapolis, Indiana
Independence, Missouri
Peoria, Illinois
Springfield, Illinois
Madison, Wisconsin
Omaha, Nebraska
St. Joseph, Missouri
Lafayette, Indiana
Toledo, Ohio
Columbia, Missouri
Livonia, Michigan
Chicago, Illinois
Waterloo, Iowa
Rockford, Illinois
Sterling Heights, Michigan
Green Bay, Wisconsin
Cicero, Illinois
Joliet, Illinois
Decatur, Illinois
Topeka, Kansas
Aurora, Illinois
South Bend, Indiana
Schaumburg, Illinois
Elgin, Illinois
Waukegan, Illinois
Champaign, Illinois
St. Louis, Missouri
Kenosha, Wisconsin
Bolingbrook, Illinois
Evansville, Indiana
Bloomington, Illinois
Arlington Heights, Illinois
Rochester Hills, Michigan
Springfield, Missouri
Troy, Michigan
Lee's Summit, Missouri
Waukesha, Wisconsin
Evanston, Illinois
Kansas City, Kansas
Brooklyn Park, Minnesota
Ann Arbor, Michigan
O'Fallon, Missouri
Davenport, Iowa
Palatine, Illinois
Duluth, Minnesota
Fargo, North Dakota
Fishers, Indiana
Rochester, Minnesota
Des Moines, Iowa
Bloomington, Indiana
Overland Park, Kansas
Bloomington, Minnesota
Naperville, Illinois
Sioux Falls, South Dakota
Minneapolis, Minnesota
Lincoln, Nebraska
Wyoming, Michigan
Appleton, Wisconsin
Cedar Rapids, Iowa
Carmel, Indiana
Sioux City, Iowa
Lawrence, Kansas
Plymouth, Minnesota
Iowa City, Iowa
Rapid City, South Dakota
Olathe, Kansas
West Palm Beach, Florida
Lauderhill, Florida
Augusta, Georgia
Baltimore, Maryland
Norfolk, Virginia
Lake Charles, Louisiana
Savannah, Georgia
Atlanta, Georgia
Largo, Florida
Roanoke, Virginia
Warner Robins, Georgia
Albany, Georgia
Johns Creek, Georgia
Miami Gardens, Florida
North Charleston, South Carolina
Memphis, Tennessee
Newport News, Virginia
Wilmington, Delaware
Miami Beach, Florida
Mobile, Alabama
Chattanooga, Tennessee
Hampton, Virginia
Portsmouth, Virginia
Richmond, Virginia
Columbus, Georgia
Miramar, Florida
Lexington, Kentucky
Birmingham, Alabama
New Orleans, Louisiana
Chesapeake, Virginia
Macon, Georgia
Baton Rouge, Louisiana
Port St. Lucie, Florida
Gulfport, Mississippi
Louisville, Kentucky
Greenville, North Carolina
Montgomery, Alabama
Suffolk, Virginia
Deltona, Florida
Athens, Georgia
Clarksville, Tennessee
Knoxville, Tennessee
Murfreesboro, Tennessee
Sunrise, Florida
Clearwater, Florida
Durham, North Carolina
Fayetteville, North Carolina
Lakeland, Florida
Huntsville, Alabama
Jacksonville, Florida
Alexandria, Virginia
Jacksonville, North Carolina
Lafayette, Louisiana
Little Rock, Arkansas
Sandy Springs, Georgia
Fort Lauderdale, Florida
Kenner, Louisiana
Pompano Beach, Florida
Orlando, Florida
St. Petersburg, Florida
Columbia, South Carolina
Lynchburg, Virginia
Deerfield Beach, Florida
Gastonia, North Carolina
Plantation, Florida
Boca Raton, Florida
Hollywood, Florida
Tampa, Florida
Shreveport, Louisiana
High Point, North Carolina
Coral Springs, Florida
Washington, District of Columbia
Davie, Florida
Pembroke Pines, Florida
Hoover, Alabama
Melbourne, Florida
Palm Bay, Florida
Greensboro, North Carolina
Miami, Florida
Fayetteville, Arkansas
Nashville, Tennessee
Palm Coast, Florida
Charleston, South Carolina
Jackson, Mississippi
Tuscaloosa, Alabama
Cape Coral, Florida
Gainesville, Florida
Springdale, Arkansas
Concord, North Carolina
Hialeah, Florida
Boynton Beach, Florida
Tallahassee, Florida
Winston-Salem, North Carolina
Charlotte, North Carolina
Fort Smith, Arkansas
Raleigh, North Carolina
Charleston, West Virginia
Jonesboro, Arkansas
Wilmington, North Carolina
Roswell, Georgia
Virginia Beach, Virginia
Cary, North Carolina
Mount Pleasant, South Carolina
Rock Hill, South Carolina
Asheville, North Carolina
Newark, New Jersey
Trenton, New Jersey
Camden, New Jersey
Paterson, New Jersey
Brockton, Massachusetts
Nashua, New Hampshire
Jersey City, New Jersey
Elizabeth, New Jersey
Erie, Pennsylvania
Clifton, New Jersey
Passaic, New Jersey
Albany, New York
Waterbury, Connecticut
Union City, New Jersey
Philadelphia, Pennsylvania
Buffalo, New York
Reading, Pennsylvania
Schenectady, New York
Pittsburgh, Pennsylvania
Lynn, Massachusetts
Providence, Rhode Island
Rochester, New York
Stamford, Connecticut
Pawtucket, Rhode Island
Bridgeport, Connecticut
Fall River, Massachusetts
Allentown, Pennsylvania
New York, New York
Lawrence, Massachusetts
Bethlehem, Pennsylvania
New Britain, Connecticut
Springfield, Massachusetts
Danbury, Connecticut
Hartford, Connecticut
Syracuse, New York
Lowell, Massachusetts
Cranston, Rhode Island
Mount Vernon, New York
New Rochelle, New York
Boston, Massachusetts
Scranton, Pennsylvania
Portland, Maine
Manchester, New Hampshire
Somerville, Massachusetts
New Haven, Connecticut
Cambridge, Massachusetts
Norwalk, Connecticut
Warwick, Rhode Island
Quincy, Massachusetts
Worcester, Massachusetts
Newton, Massachusetts
New Bedford, Massachusetts
Yonkers, New York
Burlington, Vermont
City, State
% Prevelance of sleep less than 7 hours
% Prevalence with current asthma
Median air quality by state:
good
poor
Data Source: Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Division of Population Health. 500 Cities Project Data. 2018
Visualization by: Amanda Anderson-Tou, 2020

Insufficient Sleep & Asthma: Visualization from Climate & Sleep Thesis Project



Detailed view



Detailed view of legend

Sleep apnea is defined as a disorder of interrupted breathing when sleeping.[30] Sleep apnea is not caused by a reaction to air pollution, but rather it occurs in association with fat accumulation, and muscle changes with aging or due to neurons that control breathing experiencing malfunction while a person is sleeping. The sleeping person experiences their windpipe collapse and is awakened when their blood oxygen level falls and they can then use their upper airway muscles to resume breathing. This cycle can

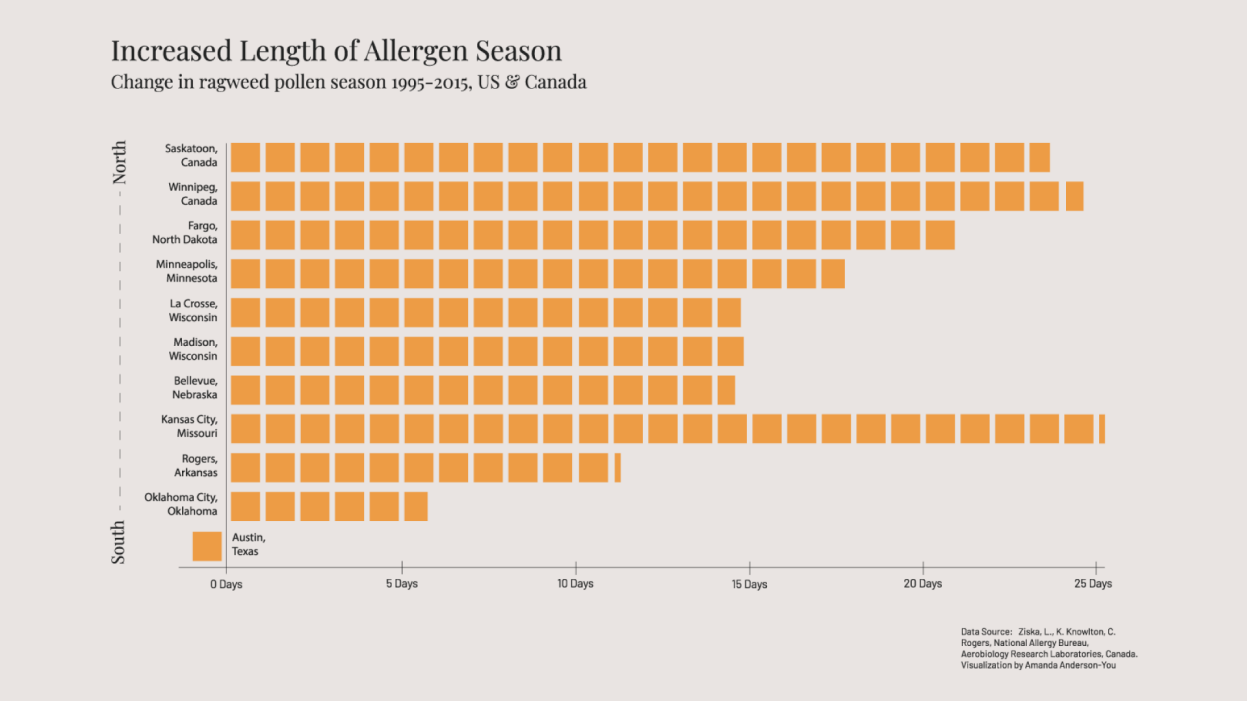
happen hundreds of times in one night. The effect of chronic air pollution exposure on obstructive sleep apnea (OSA) was explored in a study by Billings and colleagues in 2019. The key findings were that chronic exposure to ambient air pollution was associated with OSA. Additionally, exposure to higher levels of nitrogen dioxide and particulate matter (PM) 2.5 was associated with greater odds of moderate to severe obstructive sleep apnea. However, over a 5-year average, there was a lack of association attributable to PM 2.5. These measures, while associative, are recommended to be interpreted cautiously because the reduction in sleep efficiency was arbitrary.[27] Because a person with obstructive sleep apnea is struggling to breath as they sleep, the quality of the air matters greatly.

EXTENDED ALLERGEN SEASON

Another contributor to deteriorating air quality due to climate change is the increase of aeroallergens from pollen production. The growing season for allergenic plants is increasing across the country because of rising temperatures. We are observing more dramatic effects taking place in northern climates who are more vulnerable to changes in their growing season. In cities, higher concentrations of carbon dioxide as compared to rural areas accelerates the growth of allergenic plants like ragweed.[16] Allergens are a main asthma trigger, and those who suffer from allergies experience disrupted sleep and also often disturb the sleep of those around them.

This next visualization shows how 11 cities across North America experienced changes in the length of their ragweed pollen season between the years of 1995 and 2015. The cities are ordered north to south to demonstrate how, for the most part, the further north a location is, the longer the ragweed allergen season is extended. In one instance, in the furthest south location recorded of Austin, Texas, the season was shortened by one day. The data for this visualization is from the National Allergy Bureau, Aerobiology Research Laboratories. The design was created using Adobe Illustrator. It will be important to continue tracking growing season changes, as it will determine how agriculture and farming will need to adjust and potentially relocate with the climate crisis.

[27] Billings, 2019



Increased Length of Allergen Season: Visualization from Climate & Sleep Thesis Project

All in all, studies have shown that improving air quality should help both sleep and respiratory health and conceivably lower the pervasiveness and severity of asthma and obstructive sleep apnea.[7] There are steps homeowners can take to limit indoor air pollution, such as using low VOC paint, not smoking, using proper ventilation when cooking, and more. There is less control in limiting outdoor air pollution on an individual level, however there are mitigation techniques that can be incorporated into your daily schedule and decision making. Large scale changes can and should be promoted through exercising your right to vote and support protective environmental policy changes.

RISING TEMPERATURES

Along with changes in air quality, rising temperatures is another major factor of the climate crisis that impacts sleep health. The repercussions are all connected, and self-perpetuating. With higher concentrations of carbon dioxide comes warmer temperatures and overall longer warm seasons. Warmer and drier seasons are expected to extend the

period of ozone exposure.[16] As a result, global heating continues to increase and will not begin to lower without dramatic, culture shifting, mandated changes in individual behavior and collective industry. It is notable that nighttime temperatures are warming more quickly than daytime temperatures. This is mainly due to nighttime cloud cover that creates a layer of insulation without the ability to also reflect heat back out into the atmosphere like what can be done during the day.[28]

Temperature is a main factor that affects sleep quality. In the inaugural study by Obradovich et al. relating high temperatures to sleep loss, it was determined that with 1 degree Celsius deviation in night time temperatures, insufficient sleep increases by 3 nights per 100 individuals, or, across the population of the US, approximately 9 million additional nights of insufficient sleep per month, and 110 million additional nights of insufficient sleep annually. As we have assessed previously, insufficient sleep leads to higher likelihood of numerous health risks and chronic health conditions, and therefore puts those who live in high temperature areas at even more risk of suffering from poor health.

Your circadian rhythm, also known as your 24-hour body clock, controls a normal sleep-wake cycle. It is impacted by many factors including light, diet, temperature, and more. Exposure to blue light, for example, from looking at a digital screen late at night, resets your clock and tricks your body into thinking it is time to be productive, rather than time to sleep. With temperature, your circadian rhythm relies on cues from the changes of your body's core temperature to activate your sleep and wake cycles. Thermoregulation is a main component of the circadian rhythm that helps you to fall asleep and remain asleep. As your body's core cools, the temperature drop produces sleep onset. High ambient temperatures can affect normal circadian thermoregulation by keeping the body from lowering its core temperature and therefore affecting the quality of sleep. If you're sleeping in an area with a high ambient temperature, your body will have difficulty cooling your core and producing sleep onset.[29] Additionally, once you fall asleep, you may experience disruptions to your REM (rapid eye movement) stage of sleep due to abnormally hot or cold temperatures. A person loses some ability to regulate their own body temperature during REM sleep, and if this phase of sleep is disrupted one night, it impacts the subsequent period of sleep as well. Our bodies will enter REM sleep right away and attempt to recoup lost time within this stage of sleep.[30] We are sensitive to our external

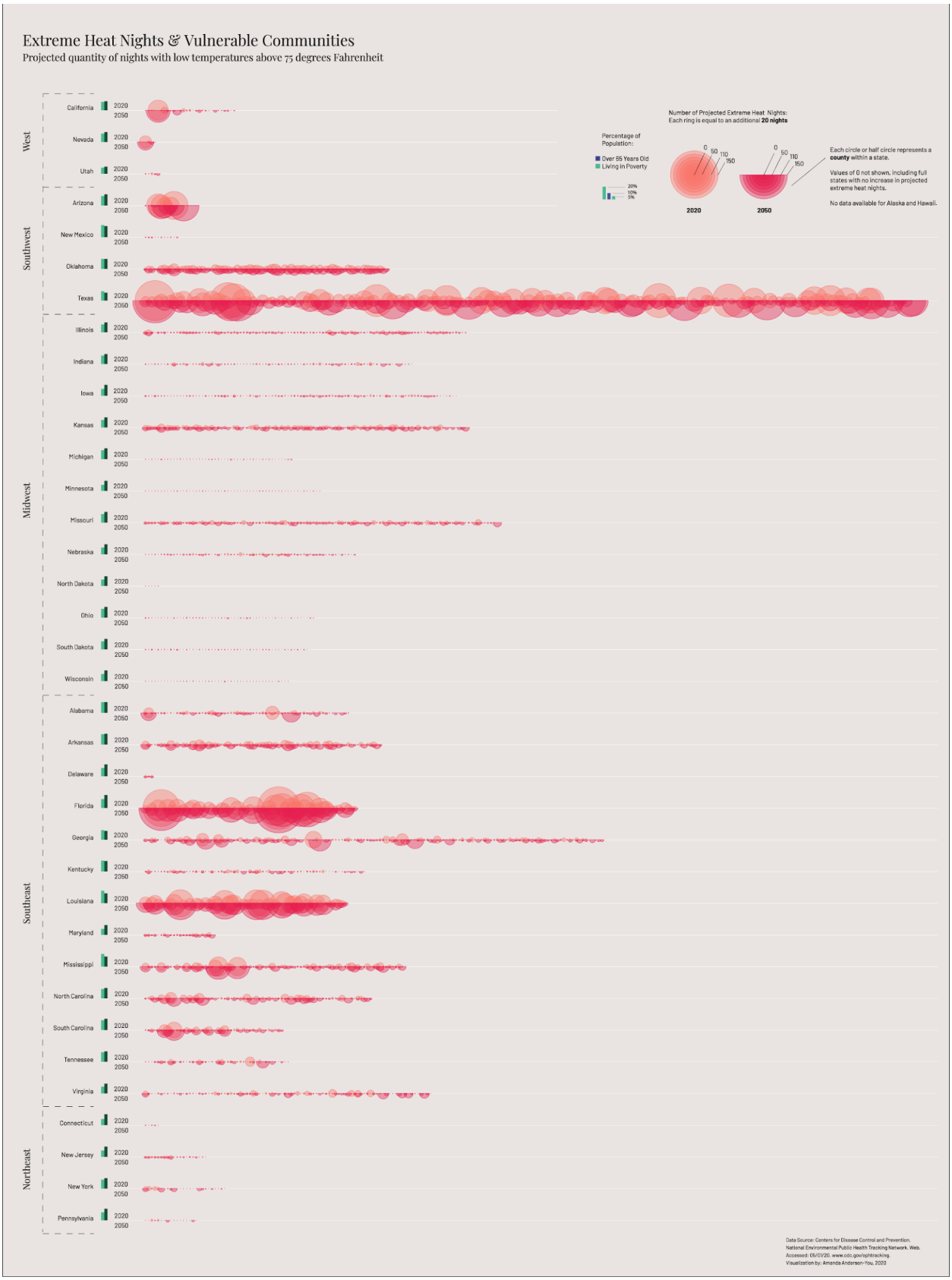
[28] Dai et al., 1999
[29] Obradovich, 2017
[30] ASA, 2016

temperatures when it comes to sleep quality. As global heating continues to expand upon quantity of extreme heat night temperatures, overall sleep health will suffer.

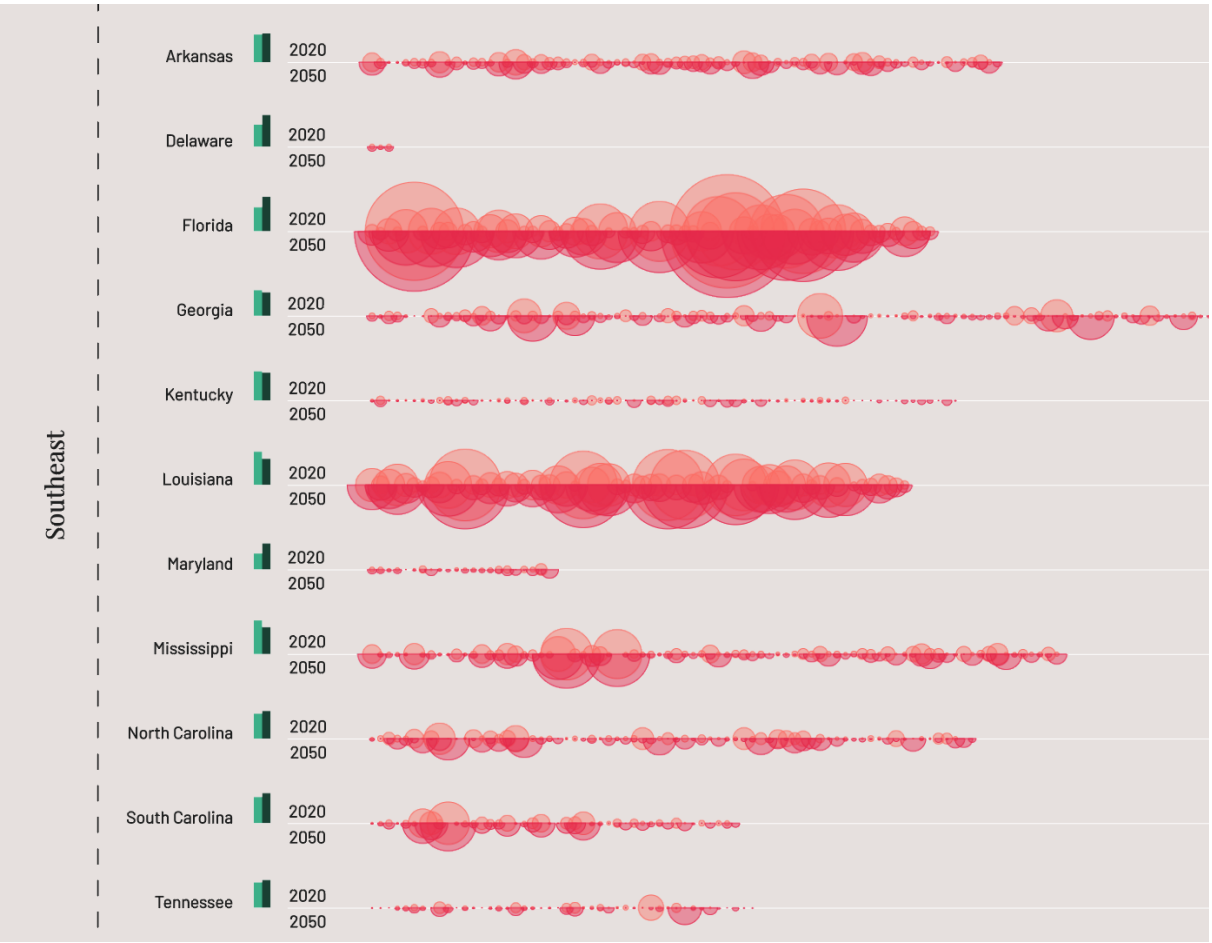
Not all people are able to manage their ambient temperature with potentially expensive to own and operate air conditioners. Those in the Southwest and Southeast regions of the United States already experience a high quantity of nights with lows above 75 degrees Fahrenheit.[31] These areas will continue to experience a dramatic increase in these extreme heat nights in the near future as temperatures continue to rise with the climate crisis. The vulnerabilities of the populations in these regions is vital to consider. These regions have the highest percentages of their population living in poverty. There are also areas with high populations of elderly people, less equipped to handle the escalation in high temperatures.

In the final visualization for Climate & Sleep I look at the quantity of extreme heat nights in both 2020 and looking toward the future with projected heat nights in 2050. This data is available at the county level and was later divided into regions to correlate with previous Climate & Sleep visualizations. In addition, I include data regarding population percentages of 65+ per state, and population percentages of people in poverty per state. This additional data helps demonstrate the vulnerable communities that are and will continue to be impacted by the increase in extreme heat nights. All of this data is available through the CDC's National Environmental Health Tracking Network. I worked with the data in CSV format and loaded it into P5.js to create the visualization. Evident in this visualization is that Texas, Florida and Louisiana all already have a high number of extreme heat nights projected for 2020 and will continue to have more in 2050. Florida also has a vulnerable population of approximately 20 percent over the age of 65. Louisiana has an at-risk population of nearly 20 percent of their population living in poverty. These communities are not as well equipped to handle this increase in extreme heat, and their sleep health will be impacted.

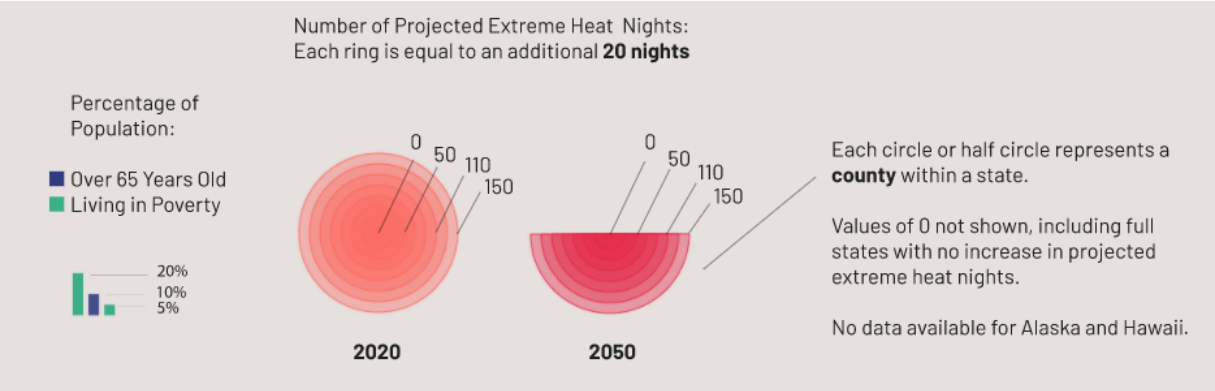
[31] CDC: Climate Change, 2017


Extreme Heat Nights & Vulnerable Communities
Projected quantity of nights with low temperatures above 75 degrees Fahrenheit
West
California
Nevada
Utah
Southwest
Arizona
New Mexico
Oklahoma
Texas
Midwest
Illinois
Indiana
Iowa
Kansas
Michigan
Minnesota
Missouri
Nebraska
North Dakota
Ohio
South Dakota
Wisconsin
Southeast
Alabama
Arkansas
Delaware
Florida
Georgia
Kentucky
Louisiana
Maryland
Mississippi
North Carolina
South Carolina
Tennessee
Virginia
Northeast
Connecticut
New Jersey
New York
Pennsylvania
2020
2050
Percentage of Population:
Over 65 Years Old
Living in Poverty
20%
10%
5%
Number of Projected Extreme Heat Nights:
Each ring is equal to an additional 20 nights
0
50
110
150
2020
2050
Each circle or half circle represents a county within a state.
Values of 0 not shown, including full states with no increase in projected extreme heat nights.
No data available for Alaska and Hawaii.
Data Source: Centers for Disease Control and Prevention, National Environmental Public Health Tracking Network. Web. Accessed: 05/01/20. www.cdc.gov/ephtracking.
Visualization by: Amanda Anderson-You, 2020

Extreme Heat Nights & Vulnerable Communities: Visualization from Climate & Sleep Thesis Project



Detailed view



Detailed view of legend

CLIMATE & MENTAL HEALTH

While mental health in relation to the climate crisis and sleep is not the focus of this thesis, it warrants mention as a relevant component. The 2018 National Climate Assessment states that extreme weather and climate-related events contribute to lasting mental health consequences for those living in affected communities, especially if they experience degradation in livelihoods or relocation. Vulnerable communities are less resilient to these extreme weather events and are more exposed to health impacts of climate change.[6] In addition, there is a spectrum of mental health consequences that can result from exposures to climate related events, whether short lived or prolonged, ranging from minimal stress symptoms to clinical disorders including depression, anxiety, post-traumatic stress, and suicidality.[32] The mental health impacts of these events can last for several years, interrupting a person's everyday life, including their quality of sleep.

Mental health is also a concern in relation to rising temperatures. In addition to stress associated with environmental degradation, displacement, and climate crisis anxiety, some people with mental illness are more vulnerable to heat. Suicide rates rise with high temperatures and some medications taken for illnesses such as schizophrenia interfere with the body's ability to regulate temperature.[33] Another condition relating to mental health and sleep is insomnia. Insomnia is the most commonly reported sleep disorder, impacting about 60 million Americans a year. Diagnoses tend to increase with age and be a symptom of an underlying medical disorder. Insomnia affects about 40 percent of women, and about 30 percent of men.[30]

CONCLUSION

The climate crisis is impacting sleep quality through poor air quality and rising temperatures. We need to implement mitigation techniques to support sleep health as global heating continues to progress because quality sleep is imperative to a person's health and well-being. With projection of climate-related changes and their implications to human health, we can begin to highlight specific risks and increase population resilience, especially for vulnerable communities. The more society can anticipate and plan for

[32] Ebi, 2018

[33] CDC: Climate Mental Health, 2019

impacts, the better they can build upon existing environmental and social programs to support citizens when climate challenges arise. Getting enough sleep at the right times is crucial for mental health, physical health, quality of life, and safety.

There are many recommended adaptive techniques to respond to the climate crisis now that should also be evolved upon in the future to continue to protect population health. In order to be effective in implementing interventions and minimize human suffering from global heating, research investments are needed to study the climate crisis' impact on health. There are basic and common-sense changes that we can utilize with no delay. For example, in effort to adapt to increased air pollution, a mitigation technique would be to opt to stay indoors when air pollution monitors report poor conditions and reschedule outdoor events to limit exposure. When it comes to rising temperatures, developing a comprehensive response plan in the event of extreme heat is an adaptive measure. As a suggested adaptive measure, The National Climate Assessment recommends coping with increased mental health issues surrounding extreme weather events by practicing "social cohesion, good coping skills, and preemptive disaster planning".[12] On a big-picture scale, overtly taking climate risks into account within infrastructure planning, urban design, increasing tree shade, increasing protective measures such as heat wave early warnings and creating more resilient power grids are more ways to adapt to the climate crisis and benefit overall health. It is imperative to climate-proof healthcare infrastructure. The climate crisis will continue to challenge our daily lives in big and small ways. By understanding how global heating is affecting human sleep quality presently, we can create adaptive measures to protect our health and well-being in the future.

BIBLIOGRAPHY

Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, et al. The National Sleep Foundation's sleep time duration recommendations: methodology and results summary. Sleep Health. 2015;1(1):40–43.

Rifkin, Daniel I., et al. "Climate Change and Sleep: A Systematic Review of the Literature and Conceptual Framework." Sleep Medicine Reviews, vol. 42, Dec. 2018, pp. 3–9., doi:10.1016/j.smrv.2018.07.007.

M. Hafner, M. Stepanek, J. Taylor, W.M. Troxel, C. van Stolk Why sleep matters—the economic costs of insufficient sleep: a cross-country comparative analysis, Rand Health Quarterly, 6(4)(2017), p. 11

L. Tenero, G. Piacentini, L. Nosetti, E. Gasperi, M. Piazza, M. Zaffanello Indoor/outdoor not-voluptuary-habit pollution and sleep- disordered breathing in children: a systematic review, Transl Pediatr, 6(2)(2017), pp. 104-110

U.S. Global Change Research Program. "Fourth National Climate Assessment: Summary Findings." NCA4, Jan. 2018, nca2018.globalchange.gov/.

Nolte, C.G., P.D. Dolwick, N. Fann, L.W. Horowitz, V. Naik, R.W. Pinder, T.L. Spero, D.A. Winner, and L.H. Ziska, 2018: Air Quality. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 512–538. doi: 10.7930/NCA4.2018.CH13

Ebi, K.L., J.M. Balbus, G. Luber, A. Bole, A. Crimmins, G. Glass, S. Saha, M.M. Shimamoto, J. Trtanj, and J.L. White-Newsome, 2018: Human Health. In Impacts, Risks, and Adaptation in

the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 539–571. doi: 10.7930/NCA4.2018.CH14

Gifford, Eva, and Robert Gifford. 2016. "The Largely Unacknowledged Impact of Climate Change on Mental Health." Bulletin of the Atomic Scientists 72 (5): 292–97. doi:10.1080/00963402.2016.1216505.

Obradovich, Nick et al. "Nighttime temperature and human sleep loss in a changing climate." Science advances vol. 3,5 e1601555. 26 May. 2017, doi:10.1126/sciadv.1601555

Robotham, Dan. "Sleep as a Public Health Concern: Insomnia and Mental Health." Journal of Public Mental Health 10.4 (2011): 234-7. ProQuest. 18 Mar. 2020.

Berry, Helen L., et al. "The Case for Systems Thinking about Climate Change and Mental Health." Nature Climate Change 8.4 (2018): 282-90. ProQuest. 18 Mar. 2020.

Mutlu, Gö, and Yü Peker. "Air Pollution, Asthma, and Sleep Apnea: New Epidemiological Links?" Annals of the American Thoracic Society 16.3 (2019): 307-8. ProQuest. 18 Mar. 2020.

Billings ME, Gold D, Szpiro A, Aaron C, Jorgensen N, Gassett A, et al. The association of ambient air pollution with sleep apnea: The MultiEthnic Study of Atherosclerosis. Ann Am Thorac Soc 2019;16:363–370

"WHO Global Ambient Air Quality Database (Update 2018)." World Health Organization, World Health Organization, 8 July 2019, www.who.int/airpollution/data/cities/en/.

Balbus, J., A. Crimmins, J. L. Gamble, D. R. Easterling, K. E. Kunkel, S. Saha, and M. C. Sarofim, 2016: Ch. 1: Introduction: Climate change and human health. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment., U.S. Global Change Research Program, Washington, DC, 25–42. doi:10.7930/J0VX0DFW.

Watson NF, Badr MS, Belenky G, Bliwise DL, Buxton OM, Buysse D, Dinges DF, Gangwisch J, Grandner MA, Kushida C, Malhotra RK, Martin JL, Patel SR, Quan SF, Tasali E. Recommended amount of sleep for a healthy adult: a joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society. SLEEP 2015;38(6):843–844.

"Sleep Health." Sleep Health | Healthy People 2020, Office of Disease Prevention and Health Promotion, asthma.

Williams, Adrian J. "Sleep Apnea." Neurology and Clinical Neuroscience, 2007, pp. 203–211., doi:10.1016/b978-0-323-03354-1.50020-1.

"Sleep Health." National Heart Lung and Blood Institute, U.S. Department of Health and Human Services, www.nhlbi.nih.gov/health-topics/education-and-awareness/sleep-health.

"Obstructive Sleep Apnoea Syndrome." World Health Organization, World Health Organization, 14 Sept. 2011, www.who.int/respiratory/other/Obstructive_sleep_apnoea_syndrome/en/.

Ohayon MM. Epidemiology of insomnia: What we know and what we still need to learn. Sleep Medicine Reviews. 2002;6(2):97–111. [PubMed]

Institute of Medicine (US) Committee on Sleep Medicine and Research; Colten HR, Altevogt BM, editors. Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem. Washington (DC): National Academies Press (US); 2006. 3, Extent and Health Consequences of Chronic Sleep Loss and Sleep Disorders. Available from: https://www.ncbi.nlm.nih.gov/books/NBK19961/

Dai, Aiguo, et al. "Effects of Clouds, Soil Moisture, Precipitation, and Water Vapor on Diurnal Temperature Range." Journal of Climate, vol. 12, no. 8, Aug. 1999, pp. 2451–2473., doi:10.1175/1520-0442(1999)0122.0.co;2.

"1 In 3 Adults Don't Get Enough Sleep." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 16 Feb. 2016, www.cdc.gov/media/releases/2016/p0215-enough-sleep.html.

"500 Cities Project: Local Data for Better Health." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 5 Dec. 2019, www.cdc.gov/500cities/.

"AAFA." Asthma Facts | AAFA.org, June 2019, www.aafa.org/asthma-facts/.

"Climate Change." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, ephtracking.cdc.gov/showClimateChangeHealth.action.

ASA Authors & Reviewers Sleep Physician, and American Sleep Association Reviewers. "What Is Sleep and Why Is It Important?" American Sleep Association, www.sleepassociation.org/about-sleep/what-is-sleep/.

"Climate Change and Public Health - Health Effects - Mental Health and Stress-Related Disorders." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 9 Sept. 2019, www.cdc.gov/climateandhealth/effects/mental_health_disorders.htm.

"Asthma & Sleep." National Sleep Foundation, 17 Apr. 2009, www.sleepfoundation.org/articles/asthma-and-sleep.

"Ground-Level Ozone Basics." EPA, Environmental Protection Agency, 31 Oct. 2018, www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics.

"Particulate Matter (PM) Basics." EPA, Environmental Protection Agency, 14 Nov. 2018, www.epa.gov/pm-pollution/particulate-matter-pm-basics.

"Sulfur Dioxide (SO2) Pollution." EPA, Environmental Protection Agency, 13 June 2019, www.epa.gov/so2-pollution.

"Nitrogen Dioxide (NO2) Pollution." EPA, Environmental Protection Agency, 13 June 2019, www.epa.gov/no2-pollution.

"Air Quality and Climate Change Research." EPA, Environmental Protection Agency, 11 Mar. 2020, www.epa.gov/air-research/air-quality-and-climate-change-research.

APPENDIX

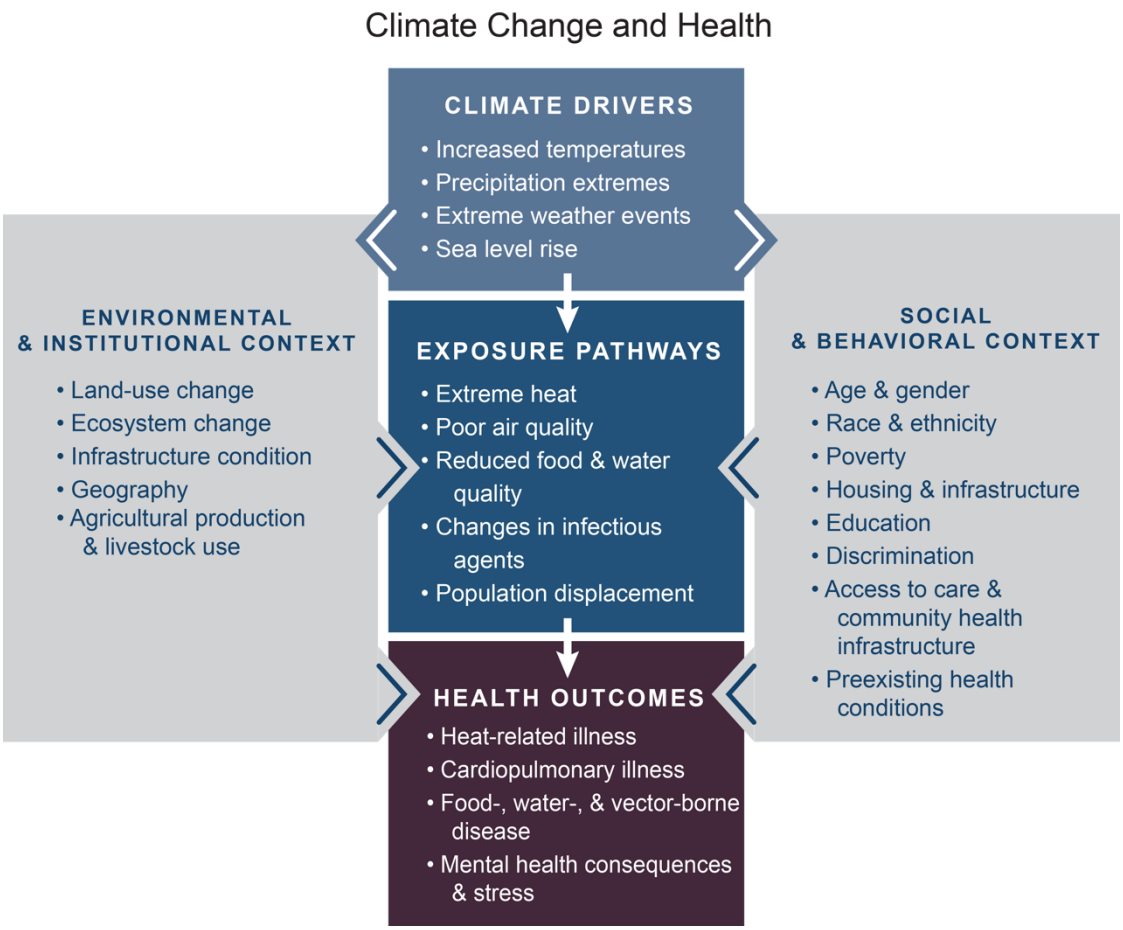


Figure 1: Climate Change Conceptual Diagram [7]