Future Physical Conditions and Climate 101 – Technical Reader

June 2022

Report produced by Good Company
for the City of Tualatin

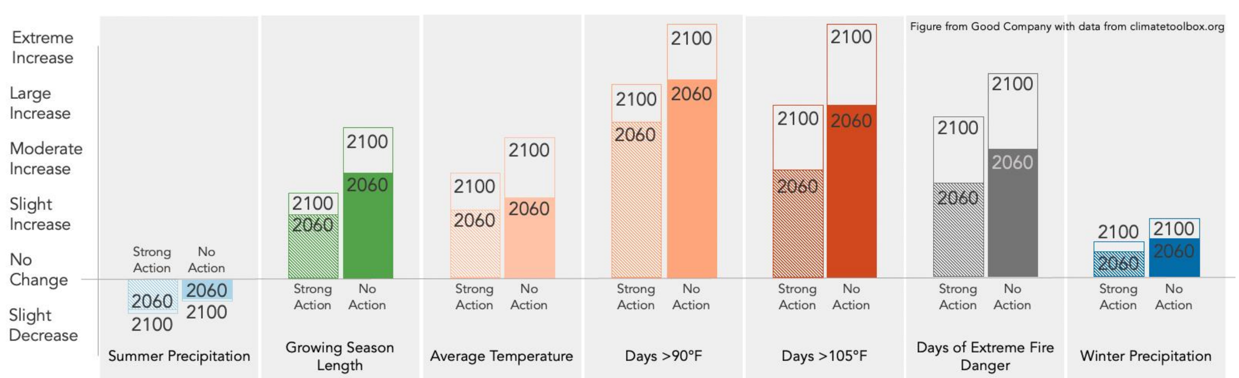
Future Physical Conditions – How Will Climate Change Affect Tualatin?

The intention of this document is to help the people of Tualatin understand the local impacts of climate change and the impact that our actions (or inactions) can have to ensure that Tualatin can continue to be a prosperous, just, and beautiful place to live. Where possible, we share what the differences in future physical conditions will be if we and the rest of the world take action to reduce emissions (Strong Climate Action scenario) compared to if we do not take action (No Climate Action scenario). Figure 1 shows a summary of the expected changes from 2060 to 2100 with and without climate action. Tualatin acknowledges that climate change will impact historically underserved communities first and worst, and is committed to devoting resources to engage with, listen to, and better serve these communities moving forward.

Snapshot: It's Going to Get Hotter with More Intense Rain Events

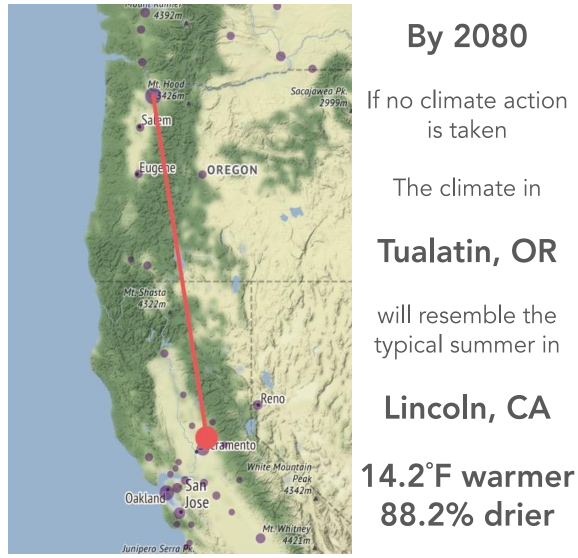
Figure 1 compares the scale of change in key factors by mid-century and by the end of the century under strong climate action and no climate action scenarios. In both scenarios, we will feel the impacts of climate change and will need to adapt but if we act quickly, we can avoid the worst of the impacts.

Figure 1: Climate change depending on global climate action (Good Company figure, Climate Toolbox data)



By the end of the century, without climate action, Tualatin is likely to ***experience a summer climate much like California's Sacramento Valley[1].*** (Figure 2) The number of days over 90 degrees every summer are expected to increase dramatically: ***from a historical average of 6 to nearly 60 by the end of the century.*** In contrast, if we take strong climate action, ***we can constrain the number of hot days to under 30.***

Figure 2: Tualatin will be like Central California



In terms of water, Tualatin will have *mostly unchanged total rainfall with an increase in big storm events ("atmospheric rivers") resulting in more rainfall over shorter periods of time***.** The Tualatin River watershed is in the coast range and does not rely on snowpack for year-round flow and so flow through Tualatin will remain largely unchanged. The Willamette River, on the other hand, relies on disappearing winter snows for its summer flow and will experience drastically decreased flows in the summer.

Wet Season

Precipitation

Overall rainfall quantities will remain nearly unchanged for Tualatin. The most noticeable change will be an increase in "atmospheric rivers", weather systems that bring large storms with heavy precipitation. Maybe Oregonians will finally start carrying umbrellas.

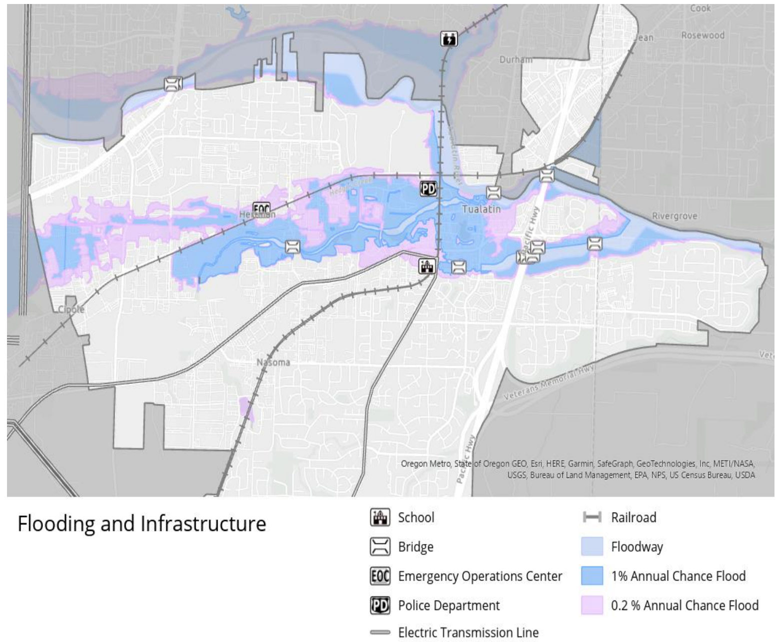
Flooding

Flooding is extremely location-specific and dependent on the local topography. Figure 3 shows the current flood map for Tualatin. The darker blue areas show where historically there has been a 1% chance of a flood occurring in a year (1 in 100 chance). This is sometimes known as the hundred-year flood. The pink area shows where the has been a 0.2% chance of flooding in a given year (known as a 500 year flood). As of the time this

[1] From University of Maryland Center for Environmental Science. https://fitzlab.shinyapps.io/cityapp/

document was written (spring 2022) FEMA had not yet released the most recent flood maps, so this map only reflects historical conditions. In the future, however, increased severity of rain events is likely to increase the likelihood and severity of flooding. The increased chance means the blue area may come to represent a 2-5% chance per year (50 to 20 year flood), and the pink areas may expect flooding every hundred instead of five-hundred years. In short, larger flooding events are becoming increasingly likely.

Figure 3: Current Flood Map

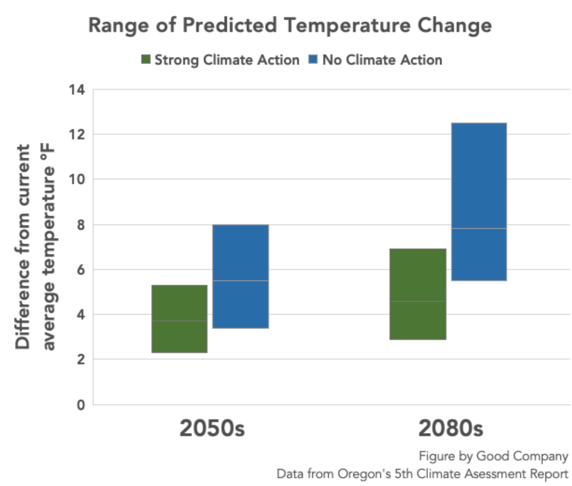


Dry Season

Heat

As mentioned before, an increase in average temperatures is expected whether we take action on climate or not, but we can avoid the worst of it (Figure 4). While rising temperatures create risk for plants and animals (including humans), higher temperatures will expand the growing season, creating an opportunity for agriculture. Under a strong climate action scenario, ***Tualatin can expect an increase in growing season from 239 days a year to 289 days a year. Under a "no change" scenario, the growing season will be nearly the whole year at 330 days.*** This change in growing season presents an opportunity for agricultural production as an increase in growing season can lead to an increase in production with appropriate crop choices. Increased

Figure 4: Expected range of temperature change by mid and late century

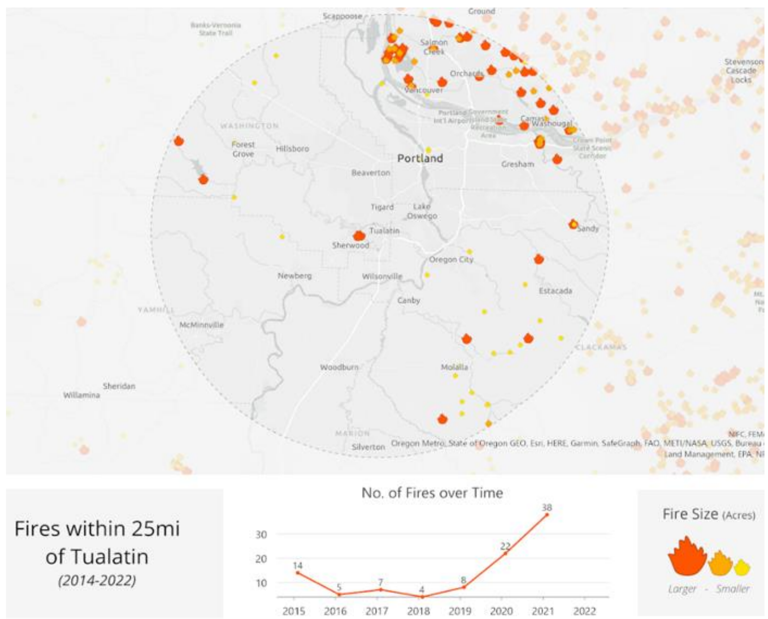


heat and decreased snow will likely lead to drought, and so increasing water storage in the Willamette basin will be critical to utilizing the expanded growing season.

Fire

The fire pattern of the forests of the Coast Range to the west of Tualatin is characterized by infrequent, high severity fires. The combination of dense Douglas fir regrowth after logging combined with an increase in summer heat is likely to intensify the fires, leading to more severe fires that will leave mostly-dead forest and increase burned areas. We are already seeing the devastating effects, as shown in Figure 5, with fires around Tualatin increasing steadily in the last few years. Without climate action, the current average of 10 days of extreme fire danger will double to 20 by the end of the century. Strong climate action can decrease the number of extreme fire danger days to 17.

Figure 5: Recent fire conditions around Tualatin



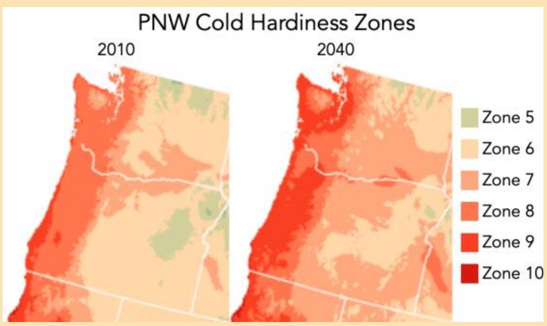
Air Pollution

Pollen levels are expected to increase with the increase in growing season, worsening seasonal allergies. Ozone levels are also expected to climb as temperatures increase, worsening asthma, emphysema, and other respiratory disorders. Wildfire smoke is expected to increase with wildfires, not just in nearby forests, but across the West. Smoke can cause and exacerbate numerous health conditions including acute respiratory disorders like asthma, but also cardiovascular disease.

Year-Round

Plant and Animal Ranges Change

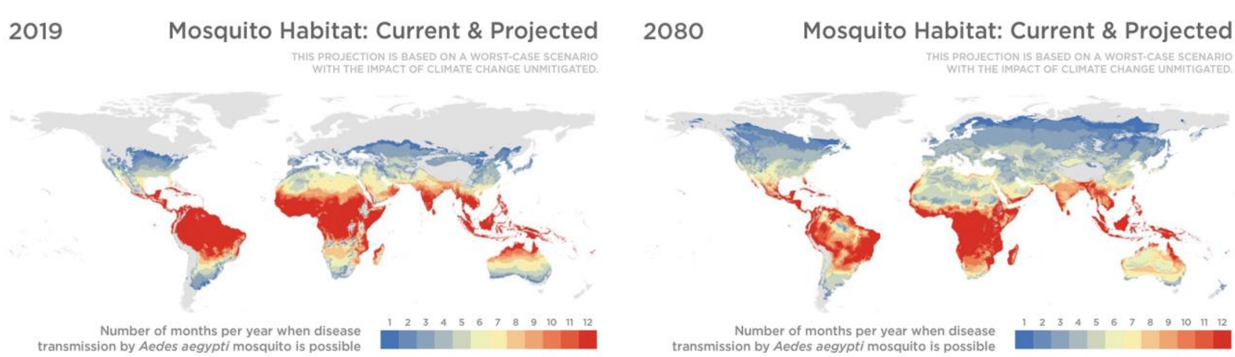
Make lemonade? The USDA defines cold hardiness zones to tell gardeners which plants will be able to survive the winter. Tualatin's zone will shift from 8b to 9a (Chico, CA) under strong climate action and to 9b (Napa, CA) under no climate action. This means more citrus trees and passion fruit but fewer apples and pears.



The ability of plants and animals to survive is affected by a combination of water availability and temperature. Changing either of those factors will result in a change in which plants and animals that can live around Tualatin. Although living things have some capacity to adapt to changes in their environment, the rate of climate change generally exceeds the rate of adaptation observed in the wild or in fossil records.

Many of the species that currently inhabit our forests and streams will not be able to survive in the changing conditions. For example, native trout and salmon are expected to decrease by 60%. Other plants and animals, on the other hand, may thrive under the new conditions. warming waters are also expected to increase the frequency of harmful algal blooms. In addition, changing conditions can also change the range of diseases. The range of the mosquito that carries malaria is predicted to shift all the way up to Alaska without climate action (Figure 76[2]).

Figure 76: Expanding malaria mosquito habitat

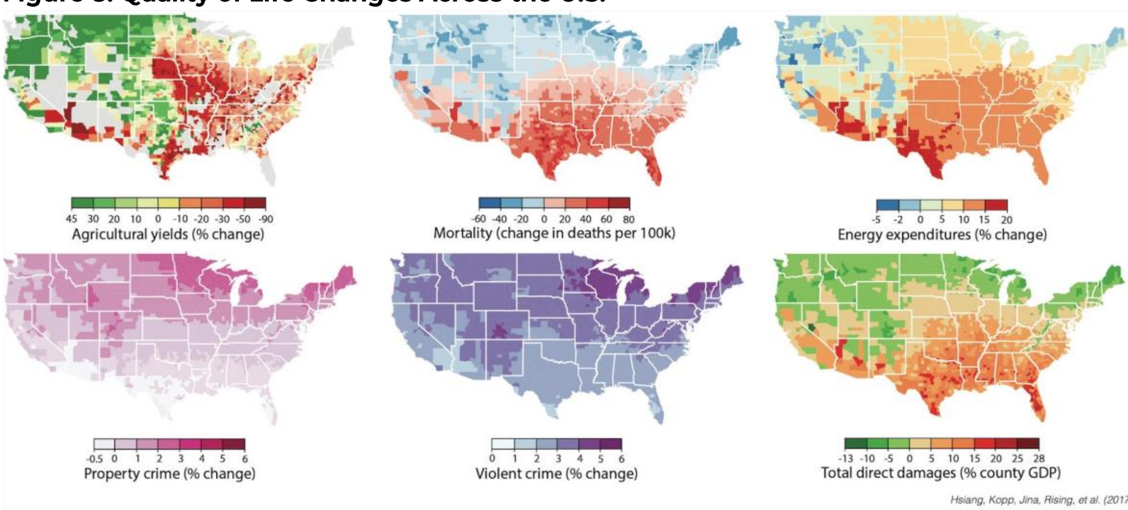


[2] Figure adapted from Ryan, S.J. et al, 2019. Global expansion and redistribution of Aedes-borne virus transmission risk with climate change. PLOS Negl Trop Dis. 13(3): e0007213

Increasing Population

The United States will experience changes across an array of sectors. Overall, the Pacific Northwest will remain one of the best places to live in the country. Figure 8[3] shows decreasing affordability and comfort in the southern and midwestern states and more moderate changes in the northwest. This will likely lead to people moving to more comfortable conditions in the northern states. As other parts of the country suffer through droughts, hurricanes, and intolerable heat waves, it is likely that the increasing population trend in the Willamette Valley will continue, resulting in higher demand for homes and resources in our area.

Figure 8: Quality of Life Changes Across the U.S.



[3] Figure adapted from *Estimating economic damage from climate change in the United States*, Hsaing et al, Science 2017

Health Effects

The Oregon Health authority put together a comprehensive assessment of how climate change will affect Oregonians' health[4]. We can expect many of the above-mentioned effects along with an increase in heat-related conditions, such as heat exhaustion and infectious diseases such as West Nile, Lyme, and fungal diseases. Furthermore, heat affects human health through increased stress and has been linked to increased violence[5] in some populations. Pregnant people, people who work outdoors, the elderly, and people without access to air conditioning are at particularly increased risk for heat stroke and other heat related conditions.

<table>
<tr><th>Climate-related drivers of health: environmental hazards</th><th>Stress factors: inequities in social, physical environment, cultural, and economic supports</th></tr>
<tr><td>Heat</td><td rowspan="2">Systemic inequities in policies</td></tr>
<tr><td>Infectious disease vectors</td></tr>
<tr><td>Wildfire</td><td rowspan="3">Inequities and unequal investment in social determinants of health (e.g., housing, education, income, wealth, transportation access, food security, income security, access to health care)</td></tr>
<tr><td>Air quality (e.g., pollen, wildfire smoke, smog, ozone)</td></tr>
<tr><td>Storms, floods, landslides</td></tr>
<tr><td>Sea level rise</td><td rowspan="2">Capacity and adaptive capacity of infrastructure, institutions, and systems to support human health (e.g., culturally specific services, surge capacity of hospitals)</td></tr>
<tr><td>Drought, water insecurity</td></tr>
<tr><th colspan="2">Effects on human health</th></tr>
<tr><td colspan="2">Hazard-related acute conditions (e.g., heat stroke, asthma attack)</td></tr>
<tr><td colspan="2">Hazard-related chronic conditions (e.g., heart disease, diabetes, respiratory illness)</td></tr>
<tr><td colspan="2">Infectious diseases (e.g., Lyme disease)</td></tr>
<tr><td colspan="2">Mental health conditions</td></tr>
<tr><td colspan="2">Adverse pregnancy outcomes</td></tr>
</table>

[4] Table from OHA Climate assessment report

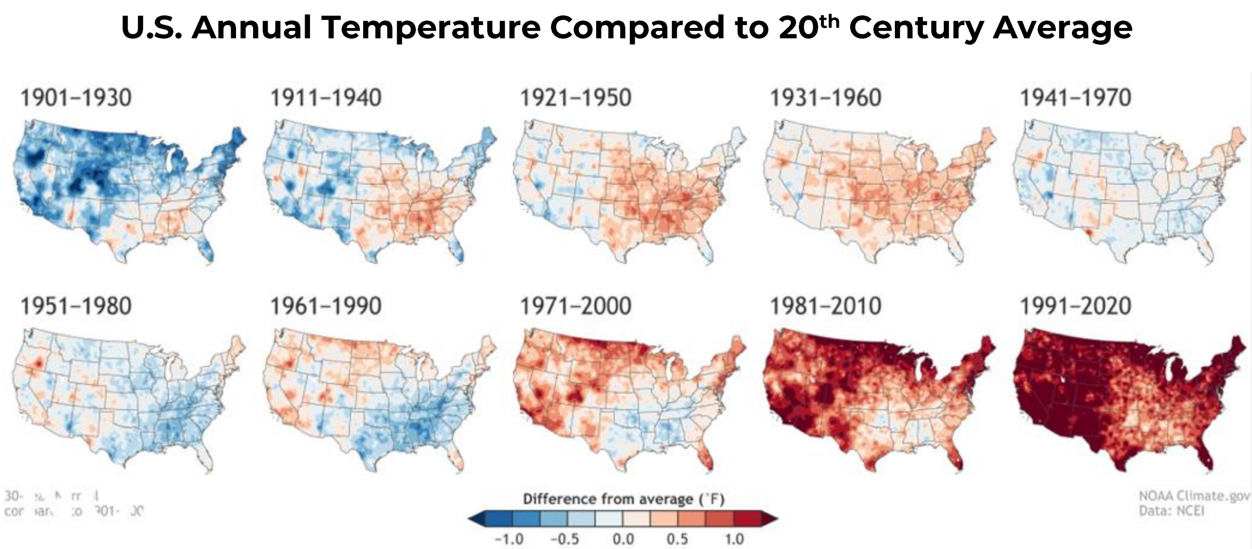
[5] "The Causal Effect of Heat on Violence: Social Implication of Unmitigated Heat Among the Incarcerated" Anita Mukherjee and Nicholas J Saunders, National Bureau of Economic Research Working Paper 2021

Climate 101

How Do We Know Climate Change Is Actually Happening?

The average temperature has unmistakably been going up over the last century, way beyond what we have seen before. This is supported by a wide range of evidence from melting glaciers[6] and polar ice caps[7] to earlier bird migrations[8].

Figure 9: Increasing temperatures across the U.S.



> ***What is a Greenhouse Gas (GHG)?*** Greenhouse gasses are any of a number of gasses that trap heat in the atmosphere, causing the greenhouse effect. Some are naturally produced: we breathe out carbon dioxide (CO_2) and cow burps contain methane (CH_4). These can also be released through human activity: burning wood or coal releases CO_2 and decomposition in landfills releases CH_4. Burning fossil fuels such as coal and natural gas accounts for 85% of the human caused CO_2 emissions. Some GHGs are synthetic: hydroflourocarbons and other fluoridated gasses are used in industrial processes and refrigerants. CO_2 makes up most of the GHGs in the atmosphere but CH_4 and the synthetic gasses have a much greater ability to trap heat. Higher concentrations of these gasses in the atmosphere leads to more heat trapped on earth.

[6] https://www.climate.gov/news-features/understanding-climate/climate-change-glacier-mass-balance
[7] https://e360.yale.edu/digest/theres-been-a-six-fold-increase-in-polar-ice-cap-melting-since-the-1990s
[8] https://www.scientificamerican.com/article/millions-of-birds-are-migrating-earlier-because-of-warming/

What is Causing Climate Change?

Climate change is caused by increased carbon dioxide (CO2) and other greenhouse gas emissions since the industrial revolution[9]. When coal, oil, or gas are burned, they release into the atmosphere CO2 that has been trapped underground for millions of years – increasing the concentration of carbon in the atmosphere far beyond the natural balance. The massive increase in the use of fossil fuels since the industrial revolution (Figure 10[10]) has increased the concentration quickly.

Figure 8: Increasing use of fossil fuels

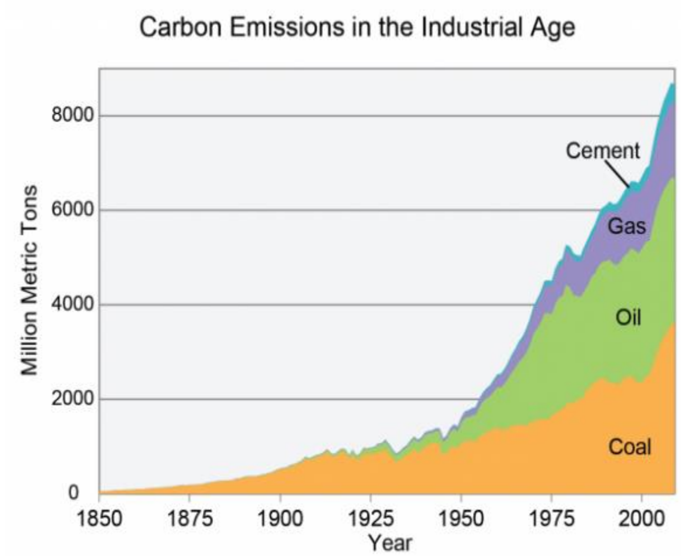
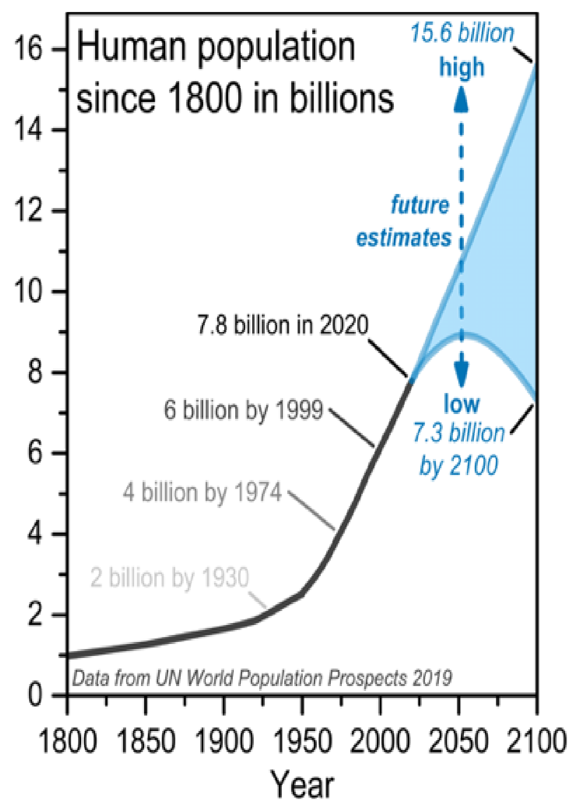


Figure 7: Increasing human population

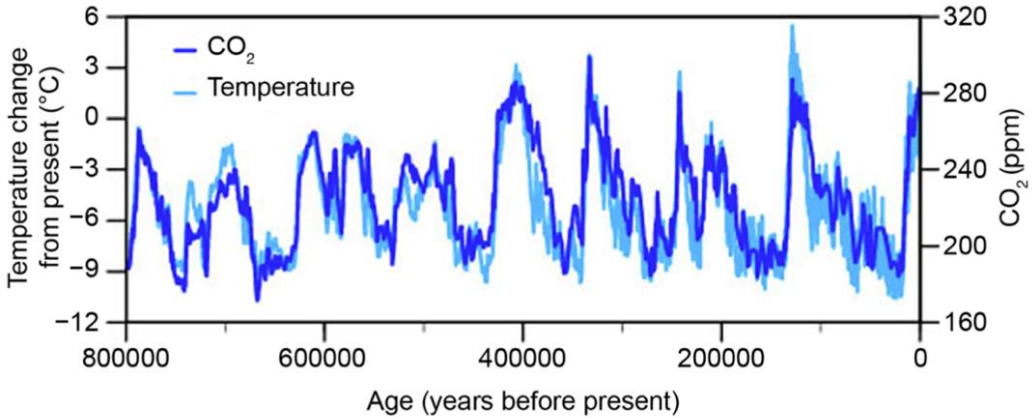


Dramatically more people on earth (Figure 11[11]) and more people burning fossil fuels is filling our atmosphere rapidly and causing the change in climate to occur. When you add widespread burning of fossil fuels to the carbon cycle, plants cannot reabsorb the amount of carbon generated quickly enough. Increased concentrations of CO2 and other greenhouse gases increase the earth's temperature via the greenhouse effect. In Figure 12 you can see how tightly correlated global temperature change and the

[9] https://www.globalchange.gov/browse/multimedia/carbon-emissions-industrial-age
[10] Figure from NOAA, Temperature Change and Carbon Dioxide Change
[11] Figure from Wikimedia Commons

concentration of carbon in the atmosphere have been through history.

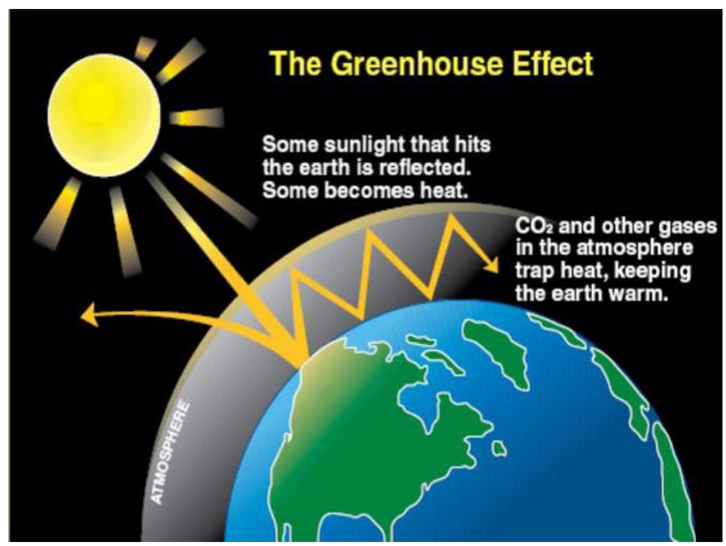
Figure 9: CO_2 and temperature are tightly linked



How Does the Greenhouse Effect Work?

The atmosphere is a thin layer that extends about 7 miles off the surface of earth. The atmosphere allows light from the sun to pass through it, but it bounces heat around, a little like a clear blanket. Light from the sun is converted to heat on earth and some of that heat is trapped by the atmosphere.

Figure 13: The greenhouse gas effect

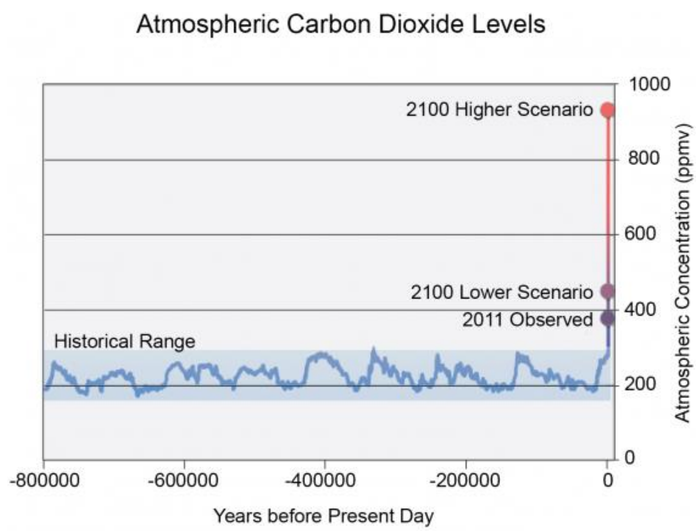


The more CO_2 (and other greenhouse gases) in the atmosphere, the more heat is prevented from escaping the earth and the hotter things get.[12] It should be noted that this is not the same as the Ozone layer, which filters out ultraviolet light, but does not interact with heat in the same way.

[12] Greenhouse effect figure created by Aaman Kler

Haven't CO_2 and Temperature and Always Bounced Around? What Makes Now Different?

Figure 10: Skyrocketing atmospheric CO_2



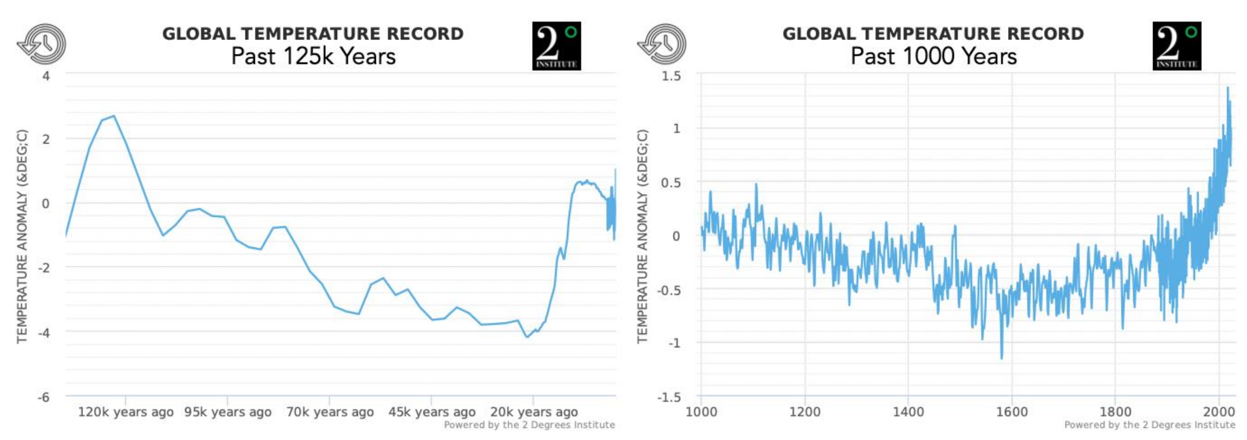
CO_2 has gone up and down over the course of human history, but it has never been nearly as high as it is right now (Figure 10[13]). For all of previous human history, CO_2 levels were dramatically lower than they are now, hovering between 200 and 300 parts per million. ***In the last 70 years, the concentration of carbon dioxide in the earth's atmosphere increased to 415 parts per million, it has not been this high since 4 million years ago, millions of years before modern humans[14]!*** Back then, the earth's temperature was an average of 7 degrees higher than now, sea levels were 80 feet higher (this would inundate most of the east cost of the US) and forests stretched all the way to the poles.[15,16] It was a very different earth.

As for temperature, yes, things were much hotter (and colder) at other times, but our current temperatures are hotter than they have been for the last thousand years. In fact, temperatures haven't been this high since more than 100 thousand years ago, when humans were just moving out of Africa.

Not only are global temperatures higher than any time during the history of civilization, but they are going up fast and the full effects of increased greenhouse gasses will continue to unfold for centuries. Without climate action, our children and grandchildren will inhabit a much hotter and more hostile world.

[13] Figure from ClimateChange.gov, Appendix 3: Climate Science Supplement of the nca3 report
[14]https://theconversation.com/climate-explained-what-the-world-was-like-the-last-time-carbon-dioxide-levels-were-at-400ppm-141784
[15] https://www.theguardian.com/science/2019/apr/03/south-pole-tree-fossils-indicate-impact-of-climate-change
[16] https://www.axios.com/earth-carbon-dioxide-levels-human-history-03dc4dc7-660a-44a9-b85c-d8777c4be8c8.html

Figure 15: Historical temperature records



How Could People Possibly Affect the Big, Huge Atmosphere So Fast?

The atmosphere is actually not that large compared to the size of the earth! It is only a thin layer. If the earth were a basketball, the atmosphere would be like a piece of cling film wrapped around it. Not so much, huh?

What is the Difference Between Climate and Weather?

Climate is the general pattern: in Tualatin's climate, we get rain in winter and sun in summer. People in another climate might experience snow in winter and thunderstorms in the summer. ***Climate is affected by long-term factors*** like latitude and distance from an ocean, while ***weather changes day to day and affected by short term factors*** like air pressure and wind.

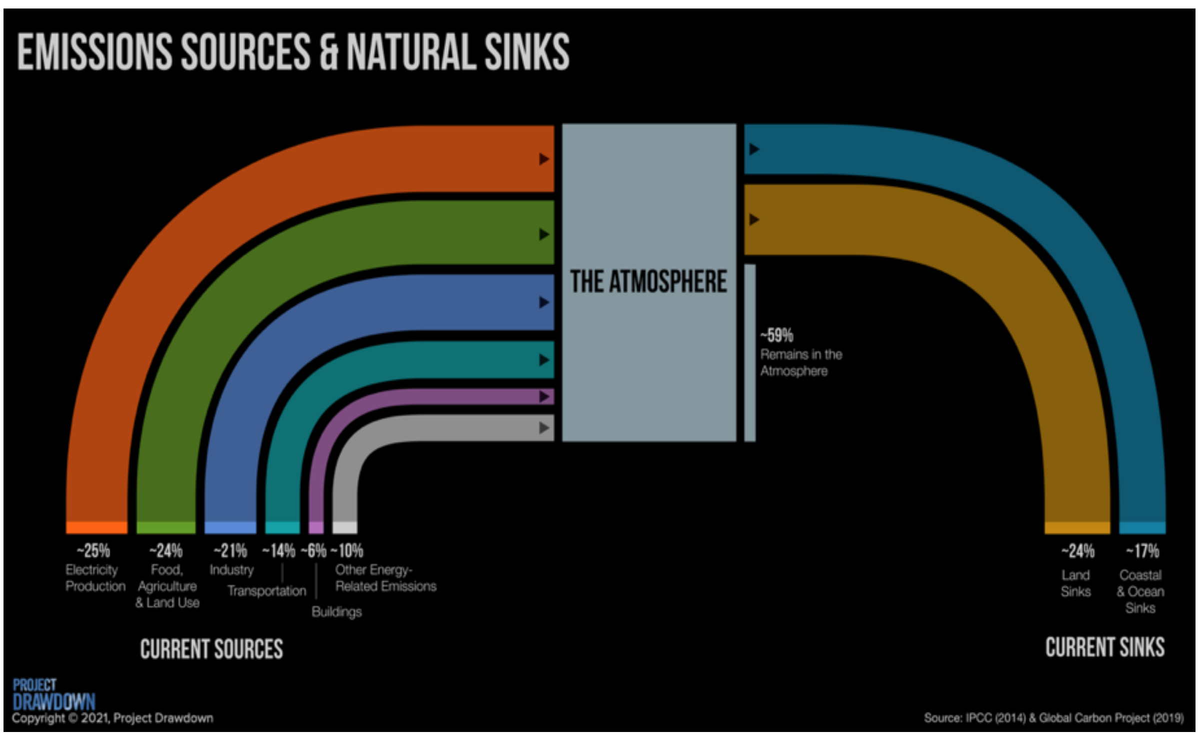
Figure 11: Climate vs weather

Doesn't the Earth Regulate Itself? Shouldn't the Plants Pull in the CO_2 and Bring Everything Back Into Balance?

Ideally yes, but our actions have added too much CO_2 for the earth to reabsorb. The earth is a complex system. There are some processes that decrease the amount of CO_2 (these are referred to as "sequestration")– the oceans can consume some of it, and so can the plants.

Theoretically, oceans, forests, and all vegetation on earth can absorb about 40% of all greenhouse gas emissions we are currently putting into the atmosphere. But increasing temperatures can also decrease the supply of water, making it more difficult for plants to grow. There are other feedback loops: melting snow turns white ice into dark rocks or water, absorbing heat instead of reflecting light; and melting permafrost means that a whole lot of frozen dead plants start to decay and release even more CO_2. We must reduce our emissions first before the natural systems can keep up.

Figure 12: Earth's emissions sources vs sinks



Is It Hopeless?

No! By switching to carbon-free electricity and fuels and employing strategies such as carbon sequestration to draw down the greenhouse gases in the atmosphere, we can avoid the worst effects of climate change. If we act now, we can improve our quality of life now, and preserve our future.

Figure 13: Climate action can lead to a better