OFFSHORE WIND FACTS

CLIMATE CHANGE

What you should know:

- While the earth's climate has changed in various ways over millions of years, scientists have concluded that global average temperatures have been rising since the Industrial Revolution as a result of carbon dioxide (CO_2) being released into the atmosphere from the use of fossil fuels like coal, oil, and natural gas.
- Climate change poses a significant risk to human health in the form of changing weather patterns that can cause more severe storms, flooding, droughts, and heat waves.
- Greenhouse gas emissions from the energy sector are the single largest contributor to climate change.
- Replacing fossil fuel energy resources with renewable energy resources like wind and solar can make a significant contribution to meeting global targets set in the Paris Climate Accord to keep average global temperatures from rising to 2°C above pre-industrial levels.

An Overview of Climate Change

Climate change refers to a global change in normal climate patterns. Not to be confused with weather, climate refers to the consistent and typical weather patterns observed in a specific place for 30 years or more. For example, in certain places the climate can be wet and cool in the winter and hot and dry in the summer, whereas the weather refers to the day-to-day changes you can observe, like rain (National Aeronautics and Space Administration [NASA], 2014). While the climate has changed before (i.e. ice ages versus greenhouse periods), the rapid pace of changes in patterns seen in recent decades can be directly attributed to human causes, specifically the burning of fossil fuels and addition of greenhouse gases into the atmosphere. This is reflected in ice cores from polar regions and alpine glaciers from around the world. These ice cores have bubbles within them that capture and preserve air from certain periods of time. By analyzing the composition of the air and the concentrations of gases held within, scientists can corroborate the atmospheric changes reflected in atmospheric data at a given time from around the globe (Alley, 2000).

Fossil fuels include substances like coal, oil, natural gas, and propane, which are used as heat sources, fuel for transportation, and power for electricity. These fossil fuels supply more than 80% of all the energy consumed by the industrially developed countries of the world (Kopp, 2023). Burning any of these fuels in a combustion reaction creates two major by-products: water and carbon dioxide (CO_2). Water vapor and greenhouse gases like CO_2 substantially contribute to climate change because they trap heat from solar radiation and prevent it from leaving the atmosphere (Kweku et al., 2018). Some of this solar radiation is absorbed in darker portions of the Earth's surface, like the sea, and some is reflected into the atmosphere as infrared radiation by lighter areas over land or in the atmosphere (i.e., clouds) (Figure 1). Greenhouse gases such as CO_2 reflect this infrared radiation back down to Earth, leaving the radiation trapped and generating more heat on the Earth's surface (Kweku et al., 2018). While CO_2 is vital to our planet's habitability (Lacis et al., 2010), it becomes a problem when the amount of CO_2 in the atmosphere continues to increase faster than the rate at which natural systems can absorb the excess.

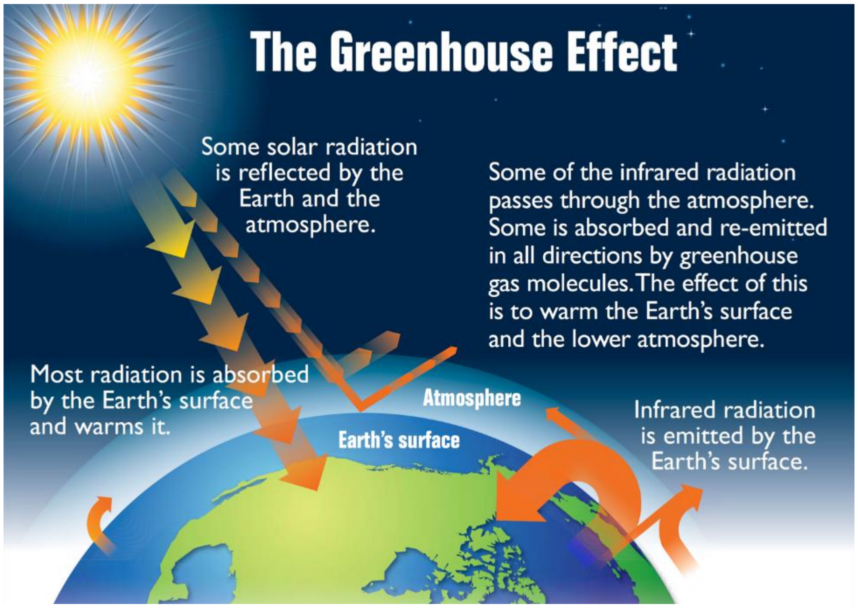


Figure 1. Describes the heat trapping process of greenhouse gases. (U.S. Environmental Protection Agency [EPA] 2023).

CO_2 is typically the most cited greenhouse gas, but methane also plays a significant role and is considered an even more potent greenhouse gas. While methane has a significantly shorter lifespan (about 7-12 years) than CO_2 (100 years or more), methane has about 80 times the heat trapping capacity, and even at the end of the 100 years, is still 25 times more potent of a greenhouse gas than CO_2 (NASA, 2023). Although methane comes from both natural sources and human activities, an estimated 60% of today's methane emissions are the result of human activities (NASA, 2023). The largest sources of methane are agriculture, fossil fuels, and decomposition of landfill waste. The concentration of methane in the atmosphere has more than doubled over the past 200 years. Scientists estimate that this increase is responsible for 20-30% of climate warming since the Industrial Revolution, which began in 1750 (NASA, 2023).

Current Status and Trends

When the level of CO_2 in the atmosphere increases, more radiation is trapped in the Earth's atmosphere, causing global temperatures to rise. The concentration of CO_2 is measured in parts per million (ppm), thus one ppm of CO_2 means that for every million molecules in the air there is one CO_2 molecule (Bridger Photonics, n.d.). Atmospheric CO_2 concentrations have increased by more than 40% since the beginning of the Industrial Revolution, from about 280 ppm in the 1800s to over 400 ppm today (Kweku et al., 2018; NOAA, 2023a; Intergovernmental Panel on Climate Change [IPCC], 2023). The increase in atmospheric CO_2 in relation to human CO_2 emissions can be seen in Figure 2.

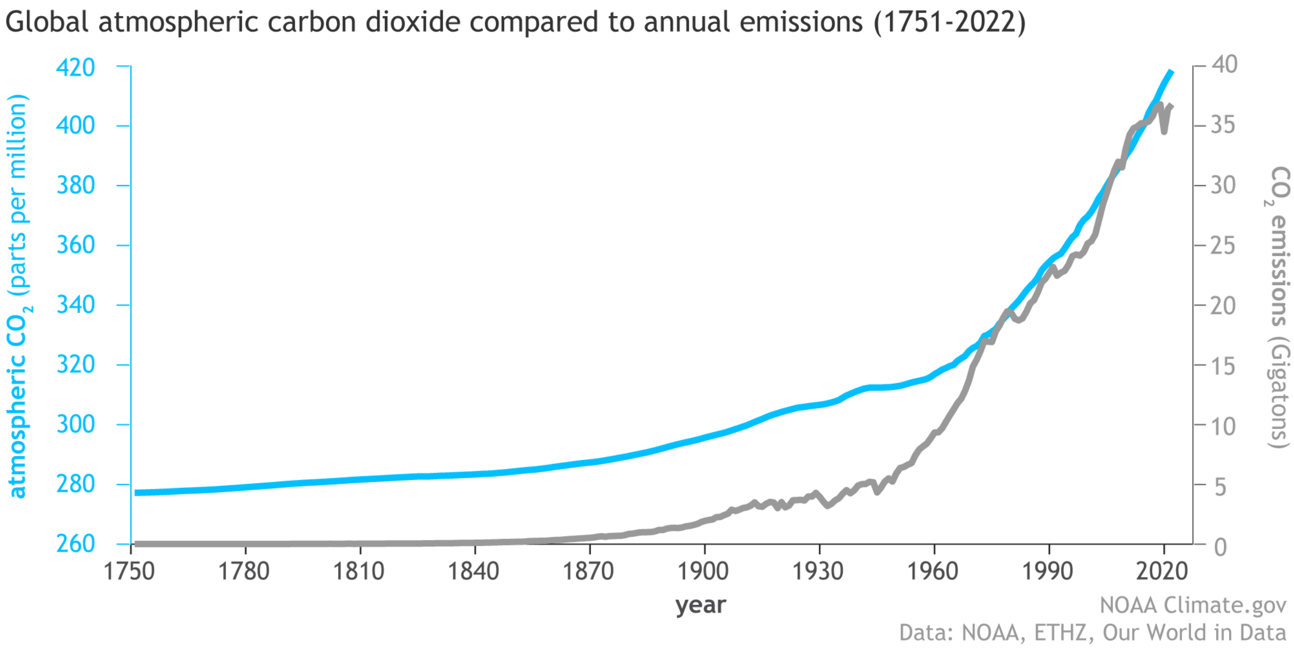
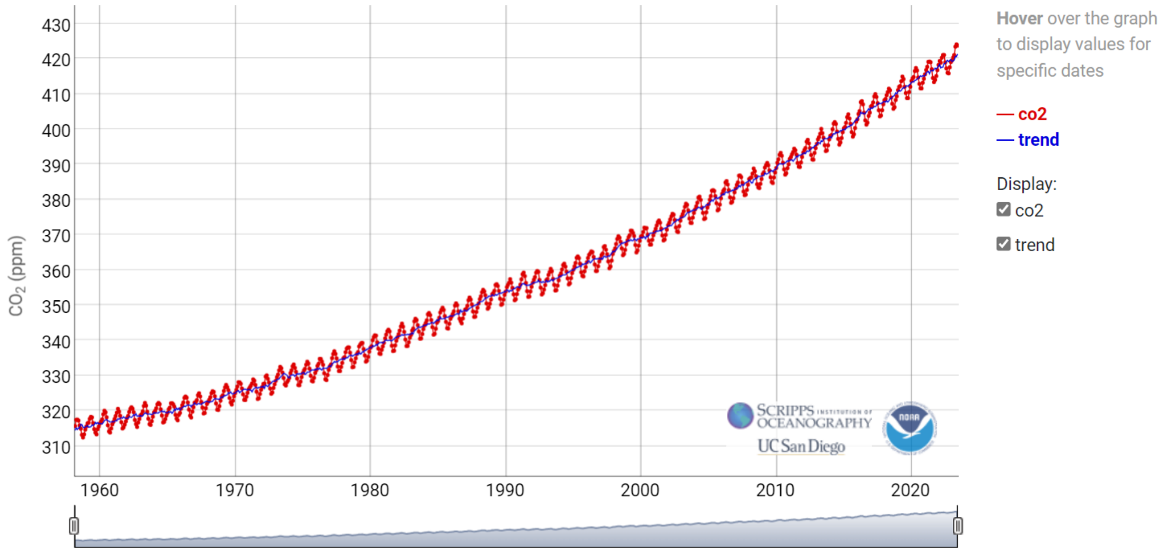


Figure 2. The amount of carbon dioxide in the atmosphere (blue line) has increased along with human emissions (gray line) since the start of the Industrial Revolution in 1750. (NOAA, 2023a)

The sharp increase in CO_2 from 1958 to 2014 becomes apparent when plotted over time at the decade scale (Keeling et al., 1995; Howe 2015), but when plotted at the monthly scale, CO_2 levels oscillate with seasonal highs and lows. This seasonal oscillation (Figure 3) occurs because the majority of land and vegetation on Earth is found in the global north, where spring and summer months from April through September represent peak growing season. Growing plants consume more CO_2, drawing down on global levels. In the winter when these plants are not actively photosynthesizing and using CO_2, global atmospheric CO_2 levels peak (Solomon, 2007). With the steady rise of global CO_2 levels driven by human activities, scientists have documented an increase in global sea-surface, air, and atmospheric temperatures (Humlum et al., 2013). In fact, to date, global average temperatures have risen roughly 2 degrees Fahrenheit (1 degree Celsius) since pre-Industrial times, and it has been 46 years since Earth has experienced a “colder than average” year (NOAA, 2023b).

Mauna Loa Monthly Averages



Mauna Loa Daily, Monthly and Weekly Averages for two years

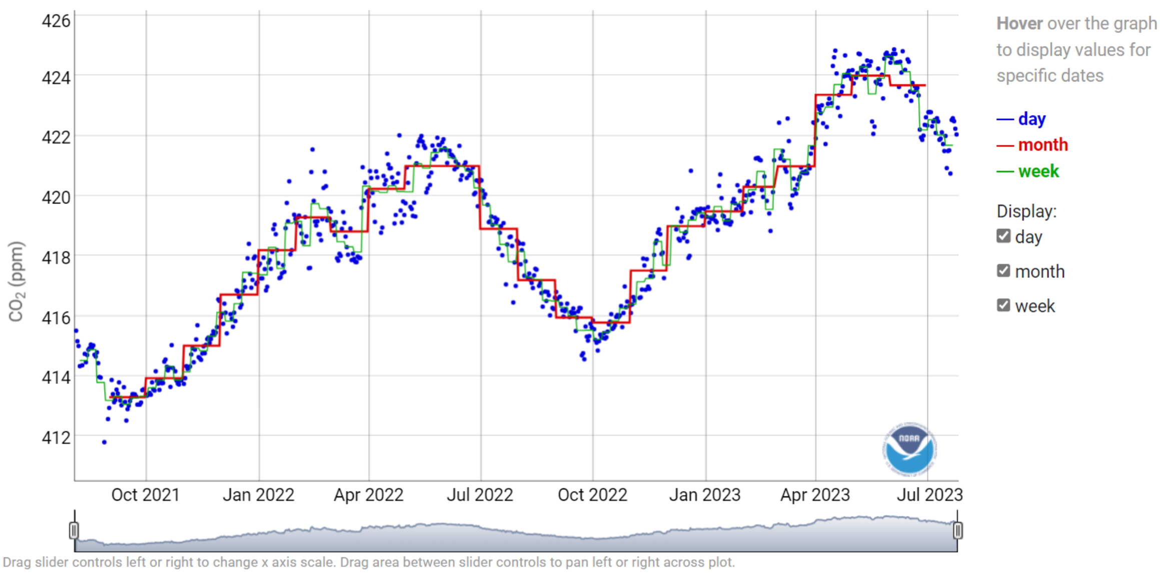


Figure 3. NOAA observations of carbon dioxide concentrations globally in a decadal and monthly scale. Observations are not linear because of seasonal changes in plant biomass (photosynthesis vs respiration globally) but the overall trend is clearly increasing at a rapid pace (NOAA, 2023 n.d.).

Effects of Climate Change

Increased global temperatures from climate change are negatively affecting people and the environment in many ways, including:

- regional and seasonal temperature extremes (NOAA, 2023b);

- increased storm intensities and prolonged hurricane seasons (Buis, 2020; National Centers for Environmental Information [NCEI], 2021);
- reduced snow and polar ice cover (Vihma, 2014; NOAA 2023b);
- sea-level rise (Alley et al. 2005); and
- erratic precipitation patterns leading to floods and droughts (NOAA 2023b; U.S. Geological Survey [USGS], 2022).

According to the World Health Organization (WHO, 2020), heatwaves killed more than 166,000 people due to extreme heat from 1998-2017, with the 2003 European heatwave alone responsible for a staggering death toll of 70,000 people. The number of people exposed to heatwaves cumulatively between 2000-2016 has increased by 125 million, compared to earlier years (WHO 2020). With heatwave temperatures setting global records in 2023 (Hersher, 2023) this number is likely to increase. Heatwaves increasingly strain the power grid as more people in industrialized nations use air conditioning to cool down, which produces even more CO_2 emissions in a negative feedback loop.

Erratic weather patterns like intensifying droughts decrease the reliability of clean water and pose major threats to agricultural stability (USGS, 2018; USGS, n.d.; IPCC, 2023). Currently about one third of the world is considered food insecure based on the Food and Agriculture Organization of the United Nations (FAO) (Wheeler & Von Braun, 2013). Increased drought severity and frequency bakes soils into hardened surfaces, which decreases the permeability of soils (FAO, n.d.), preventing water from being absorbed to recharge groundwater levels. Groundwater provides almost half of the global population with its domestic water needs (Gun, 2012), 43 % of irrigation water needs (Siebert et al., 2010), and 27 % of industrial water needs (Döll et al., 2012), while also sustaining ecologically important rivers and wetlands (de Graaf et al., 2019). If these levels are not replenished, farmers must limit by type and number of crops they can grow, contributing to food insecurity at local and regional levels. In fact, precipitation and soil moisture deficits in dry growing seasons reduced the average annual yield of the five largest crops in Australia (wheat, broad beans, canola, lupine, and barley) by 25–45% (Madadgar et al., 2017). Decreased soil permeability also drives flash flooding, soil erosion, and can strain drinking water supplies if farmers require more water to irrigate crops.

Climate change is an ongoing challenge to coastal and island communities. Natural barriers to erosion and storm surges such as coral reefs, wetlands, and mangroves are threatened by increasing temperatures, sea-level rise, and acidification of the oceans. Coral reefs act as living break walls that have been shown to reduce wave energy by up to 97% (Ferrario et al., 2014). Rising temperatures have caused global coral coverage to decline by 50% (Eddy et al., 2018) and the disappearance of these ecologically important habitats that provide important economic support to coastal communities will lead to increased coastal erosion and flooding. More information on specific climate change effects (i.e. on species, habitats, health, etc.) can be found in the individual sections of this guide.

How can offshore wind offset the effects of climate change?

Investment in clean energy technologies is an important strategy for reducing global CO_2 emissions. According to the Intergovernmental Panel on Climate Change (IPCC) 2023 Synthesis Report, energy generation diversification (e.g., wind, solar, small-scale hydroelectric) and demand side management (e.g., storage and energy efficiency improvements) will increase energy reliability and reduce vulnerabilities to climate change, especially in rural populations (IPCC, 2023). Replacing carbon-emitting fossil fuel power sources with renewable energy technologies will substantially reduce carbon emissions. In comparison with other power generation technologies, offshore wind produces 7-14% of the lifetime emissions of coal, oil, and gas plants, with an average of 7 tons of CO_2 per gigawatt hour (GWh), versus 964, 726, and 484 tons of carbon CO_2 per GWh for coal, oil, and gas plants respectively (Breeze, 2008; Esteban et al., 2011). Replacing these generation sources with wind energy avoided 336 million metric tons of CO_2 from being emitted into the atmosphere in 2022. A typical 2-megawatt (MW) wind turbine avoids around 4,000-4,500 tons of carbon emissions annually, equivalent to the annual carbon emissions of more than 700 cars. Power generated by wind (both on and offshore) in the

U.S. contributes 25% of the electricity produced in the country, supports 126,000+ jobs across all 50 states, and has delivered $140 billion in investments over the last decade. Wind energy is the second-most used renewable energy source in the world (Earth.org, 2021) and will be integral to meeting global carbon emission targets set by The Paris Agreement, which established a goal of holding “the increase in the global average temperature to well below 2°C above pre-industrial levels” and purse efforts “to limit the temperature increase to 1.5°C above pre-industrial levels” (United Nations Framework Convention on Climate Change [UNFCCC], n.d.).

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