Appendix E - Climate Change Science and Impact Context

The Greenhouse Gas Effect and Climate Change

Earth's climate is primarily driven by energy from the sun. When solar radiation reaches Earth's atmosphere, part of it is reflected back into space, while the rest is absorbed by the planet's surface. The absorbed energy heats the surface, which then radiates heat back toward the atmosphere.[1] Some of this heat escapes into space, but a portion is trapped by gases in the atmosphere known as greenhouse gases (GHGs).[2] This natural process, called the greenhouse effect (see Figure 1), is essential for maintaining temperatures that support life on Earth. However, when elevated levels of specific GHGs prevent more heat from escaping, it leads to what is known as global warming—an effect characterized by hotter-than-average temperatures—and contributes to climate change phenomena such as more intense storms, prolonged droughts, extreme heat events, and rising sea levels.[3]

Human-caused climate change is well understood and widely accepted by the scientific community, with over 97 percent of climate scientists agreeing that the planet is warming and human activities are the root cause.[4] Since the Industrial Revolution, human activities have increased atmospheric GHG concentrations from 280 parts per million (ppm) to over 410 ppm in just 150 years—a rate unprecedented in Earth's history.[5] Current CO_2 levels are now higher than at any point in the past 800,000 years, driven by activities such as burning fossil fuels, deforestation, and industrial processes.[6]

Climate change is already affecting both human and natural systems globally. Scientists have observed shrinking ice sheets, warming and acidifying oceans, rising global temperatures, reduced snow cover, sea level rise, and species extinction. These impacts pose significant risks, including flooding in low-lying areas, diminished freshwater supplies, disruptions to ecosystems, adverse public health outcomes, and a host of other environmental consequences.[7]

1 NASA. "The Causes of Climate Change," Climate Change: Vital Signs of the Planet. Available: https://climate.nasa.gov/causes.

2 UCAR. "The Greenhouse Effect | Center for Science Education," Available: https://scied.ucar.edu/learning-zone/how-climate-works/greenhouse-effect.

3 IPCC. "Summary for Policymakers — Global Warming of 1.5 °C. Available: https://www.ipcc.ch/sr15/chapter/spm/.

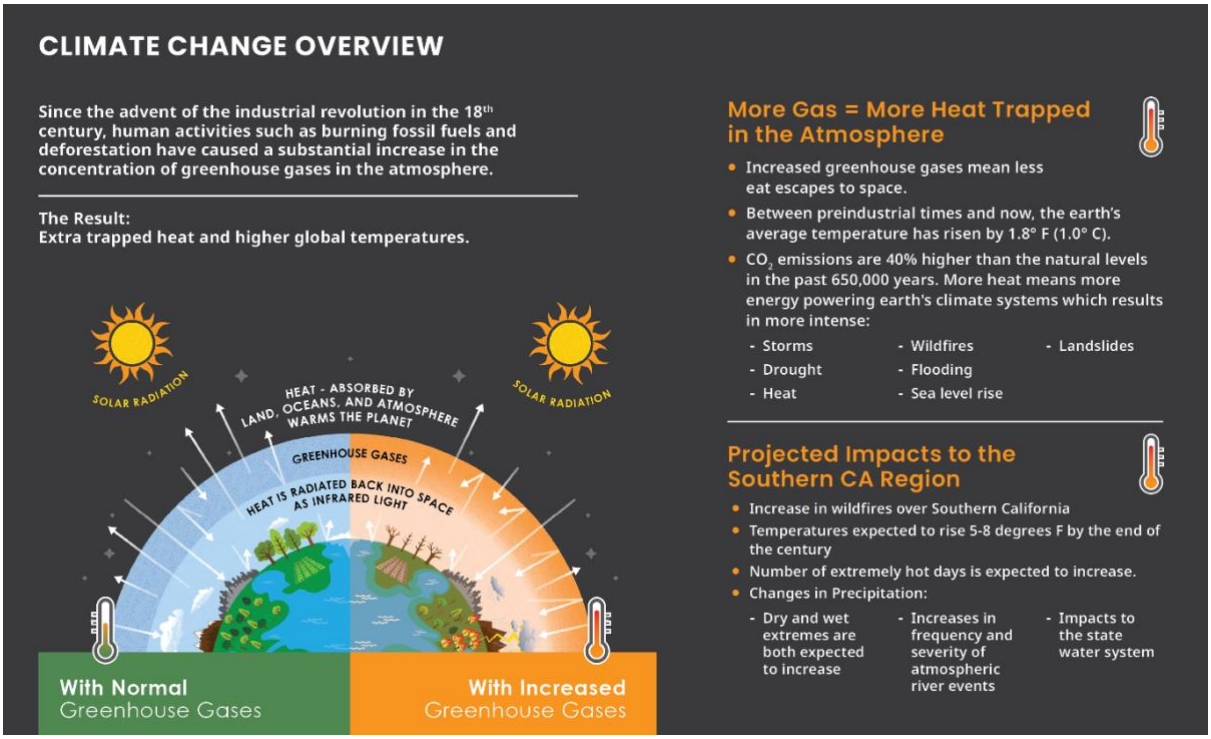
4 NASA. "Scientific Consensus: Earth's Climate Is Warming," Climate Change: Vital Signs of the Planet. Available: https://climate.nasa.gov/scientific-consensus.

5 J. Blunden and T. Boyer, "State of the Climate in 2020," *Bulletin of the American Meteorological Society* 102, no. 8. 2021. Available: https://doi.org/10.1175/2021BAMSStateoftheClimate.1.

6 Ibid.

7 IPCC. "Impacts of 1.5°C of Global Warming on Natural and Human Systems," *Assessment Report 5*. 2018. Available: https://www.ipcc.ch/sr15/chapter/chapter-3/

Figure 1 Greenhouse Gas Effect



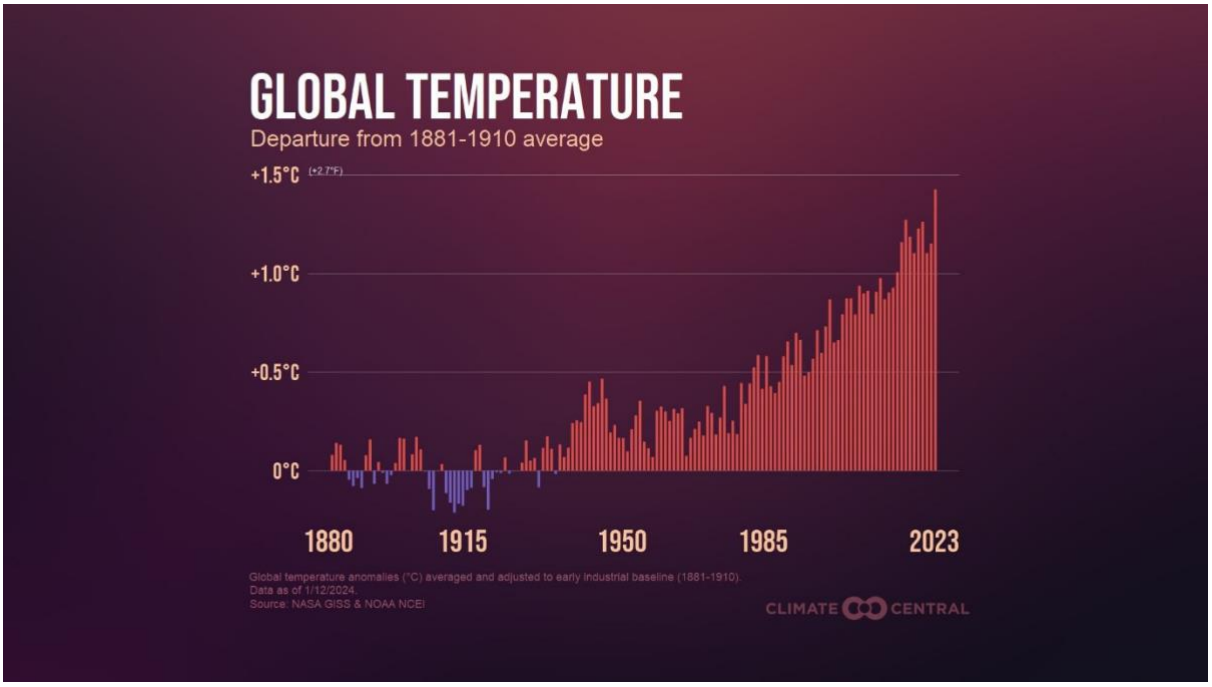
Source: National Resources Defense Council, https://www.nrdc.org/stories/greenhouse-effect-101

Globally, a warming trend is abundantly clear, with twenty-three of the hottest years on record occurring since 2000.8 The year 2023 was the hottest year on record since record-keeping began in 1880, and these trends are consistent across numerous monitoring agencies and data sets.9 NASA recorded July 2023 as the hottest month on record since 1880.10

8 NASA-GISS. "Land-Ocean Temperature Index (C): Global Mean Estimates Based on Land and Ocean Data". Available: https://data.giss.nasa.gov/gistemp/graphs/graph_data/Global_Mean_Estimates_based_on_Land_and_Ocean_Data/graph.txt.
9 NASA. "Global Surface Temperature | NASA Global Climate Change," Climate Change: Vital Signs of the Planet. Available: https://climate.nasa.gov/vital-signs/global-temperature.
Climatic Research Unit (CRU). "Land Surface Air Temperature Variations Across the Globe Updated to 2019: The CRUTEM5 Data Set," *Journal of Geophysical Research: Atmospheres* 126, no. 2. 2021. https://doi.org/10.1029/2019JD032352 Accessed:

10 https://www.nasa.gov/news-release/nasa-clocks-july-2023-as-hottest-month-on-record-ever-since-1880/

Figure 2 Global Temperature Trends



Source: Climate Central, https://www.climatecentral.org/graphic/2023-earths-hottest-year-on-record?graphicSet=Change+in+Global+Temperature+2023&location=CONUS&lang=en

While climate change is a global phenomenon, the impacts are felt acutely at the local level, affecting various aspects of society including health outcomes, access to natural resources, infrastructure resilience, emergency response systems, tourism, and the frequency and severity of disasters. According to the IPCC, achieving carbon neutrality by mid-century is essential to limit global warming to 1.5 degrees Celsius and avoiding the most severe consequences of climate change.11 To meet this critical goal, coordinated action is needed at all levels of society to significantly reduce GHG emissions.

Types of GHG Emissions

The IPCC lists the following GHGs: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), as well as chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride, which are collectively called fluorinated gases.12 Almost all the GHGs emitted in the United States each year consist of CO_2, CH_4, and N_2O, while fluorinated gases make up the remaining emissions13. Because CO_2, CH_4, and N_2O comprise a large majority of GHG emissions at the community level, these are the gases considered in this analysis.

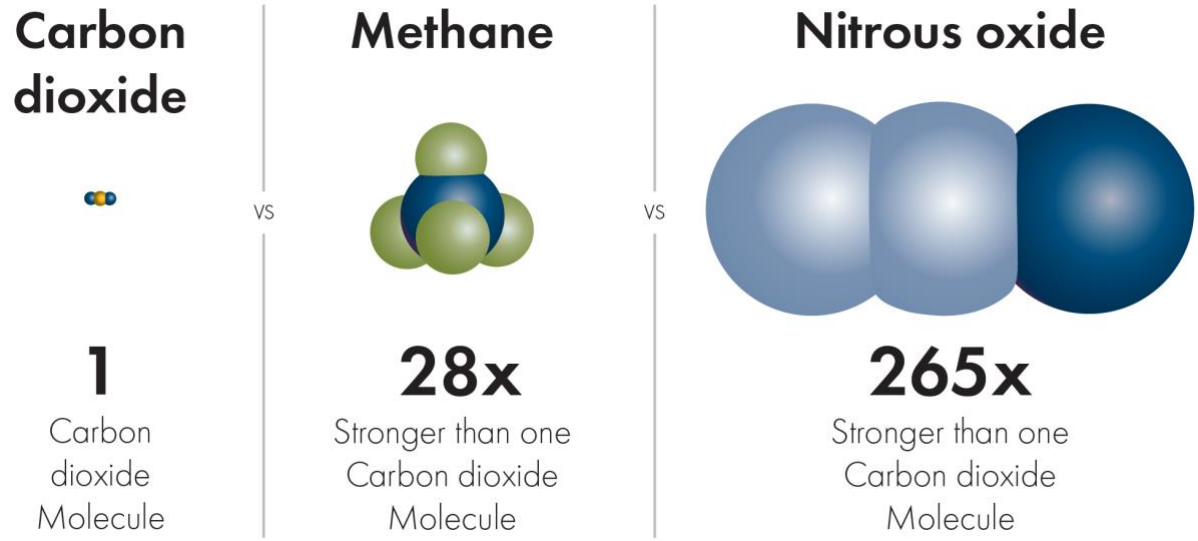
11 IPCC. "Summary for Policymakers — Global Warming of 1.5 °C". Available: https://www.ipcc.ch/sr15/chapter/spm/.

12 Note: Fluorinated gases, which includes four main types: hydrofluorocarbons 8. (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3), are man-made gases that can stay in the atmosphere for centuries and contribute to the GHG effect. Center for Climate and Energy Solutions. "Main Greenhouse Gases". 2021. Available: https://www.c2es.org/content/main-greenhouse-gases/. Accessed December 2021

13 Note: Ninety-seven percent of the annual GHG emissions consist of CO_2, CH_4, and N_2O and fluorinated gases make up the remaining three percent of GHG emissions. US EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks". 2021. Available: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks. Accessed: December 2021; World Resources Institute. "4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors". 2021. Available: https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors.

Each GHG has a different propensity for trapping heat in the atmosphere, known as the global warming potential (GWP). GHGs also last for different periods of time in the atmosphere, ranging from a decade to several thousand years. Because all the GHGs have different characteristics, a standard unit is needed to compare the potential impact of different GHGs and allow them to be added up in an analysis. This is achieved by converting all GHGs into the standard unit known as a carbon dioxide equivalent (CO_2e), based on the amount of heat one metric ton (MT) of CO_2 traps in the atmosphere. GWP for each GHG was drawn from the IPCC fifth Assessment Report (see Figure 3)14, which represents the best available scientific consensus and is consistent with the methodology outlined in the California Air Resources Board (CARB) Scoping Plan.

Figure 3 Greenhouse Gas Global Warming Potentials



14 IPCC. *Climate Change 2014: Synthesis Report*. Available: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf.; and California Air Resources Board (CARB). "California's 2022 Climate Change Scoping Plan". Available: https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents.