Sustainability Insights: Navigating Environmental Challenges through Data Exploration

Major Qualifying Project

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A Major Qualifying Project

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Executive Summary

Project Goals

Our project aims to investigate the negative impacts of greenhouse gas emissions, particularly from power plants, on the local community and advocate for necessary policy changes. Additionally, we seek to assess Worcester Polytechnic Institute's (WPI) role in combatting these emissions and propose strategies to enhance its sustainability efforts.

Introduction & Background

In confronting the immense challenges posed by the emissions of greenhouse gases we look at our local community, recognizing Massachusetts and Worcester Polytechnic Institute (WPI) as potential leaders in sustainable innovation and carbon neutrality. WPI actively fosters a sustainability culture on campus, serving as a hub for innovation in sustainability initiatives. Acknowledging the urgency of reducing carbon emissions, WPI has joined the Second Nature Group and is committed to achieving carbon neutrality swiftly. In 2020, WPI launched a five-year sustainability plan, including objectives like establishing a dedicated sustainability office and integrating sustainability projects into the curriculum. With this plan expiring in 2025, WPI has entered a $45 million public-private partnership (P3) with Harrison Street to manage on-campus utilities, focusing on sustainability initiatives.

To achieve carbon neutrality, the sustainability office at WPI monitors and manages electricity, water, and gas consumption. Despite campus expansion, WPI has reduced estimated greenhouse gas emissions, highlighting the impact of ongoing sustainability efforts. Partnering with sustainability firm GreenerU, WPI has implemented a campus-wide LED lighting system, resulting in a 53% reduction in energy usage in older buildings like Goddard Hall.

Greenhouse gases like carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) pose significant challenges to sustainability. Despite their potency, WPI recognizes the need for action. Power plants, major emitters of methane and N_2O, contribute to climate change and air pollution. Massachusetts has seen a 3.5°F temperature rise since the 1900s, highlighting the urgency of addressing emissions (NOAA, NCICS, 2022). Recognizing these issues, our project aims to investigate their local impacts, advocate for policy adjustments, evaluate WPI's efforts, and propose actionable sustainability strategies to inspire broader change.

Methods

We initiated our efforts by analyzing emissions data sourced from our local community, comprising both information provided by the WPI Office of Sustainability, as well as data from the University of Massachusetts Amherst. Our primary objective was to gauge the effectiveness of emissions reduction initiatives within our campus and among colleges across Massachusetts. As our investigation progressed, we broadened our focus to encompass greenhouse gas emissions on a national scale, extending beyond educational institutions to encompass various industries across the United States. A dataset from the EPA that documented nationwide methane, nitrous oxide, and carbon dioxide emissions was used to facilitate this expanded analysis. Employing a multifaceted approach, we integrated this EPA data with supplementary information detailing the prevalence of different health concerns throughout the nation. Through this comprehensive examination, we aimed to unravel the intricate interplay between harmful emissions and their potential ramifications for the well-being of our country.

Findings

Utilizing data from NOAA's global monitoring laboratory, our analysis shows a consistent increase in methane and nitrous oxide concentrations from 2000-2022, indicating the impact of coal-fired power plants on global warming. According to Yang & Omaye (2009), power plants significantly contribute to air pollutants linked to various health issues, including cardiovascular diseases, asthma, and COPD. Studies associate methane emissions with increased cardiovascular disease risk due to oxidative stress and inflammation (Mendoza-Cano et al., 2023). Additionally, our findings suggest a correlation between power plant density and heart disease mortality rates, indicating elevated health risks near coal-fired plants. Air pollution has been linked to increased asthma hospitalizations, and our analysis of CDC data shows a steady rise in asthma mortality rates and COPD-related deaths, underscoring the need for further investigation into environmental factors and pollutant levels.

Implications

Our analysis of EPA emissions data emphasizes the need for the implementation of robust sustainability initiatives and policies aimed at effectively mitigating greenhouse gas emissions. As climate change manifests through an alarming surge in extreme weather events, its disruptive impacts on agriculture, water resources, and ecosystems are felt far and wide, exacerbating existing health conditions and disproportionately burdening vulnerable communities (United Nations, n.d.; EPA, 2023). This pressing challenge necessitates concerted efforts to address emissions and safeguard natural systems and public health. Institutions like WPI, with their longstanding commitment to sustainability, hold a pivotal role in this endeavor. By championing proactive policy implementation and fostering a culture of environmental stewardship among community members, WPI can lead the charge in advancing sustainability goals and driving meaningful change towards a more resilient and sustainable future.

Contributions & Conclusions

The persistence of greenhouse gases underscores the urgency of sustained efforts to transition to cleaner energy sources, enhance efficiency, and implement carbon capture strategies. Our analysis revealed a concerning trend of increasing morbidity from chronic health issues, potentially linked to atmospheric pollutants. Without expedited carbon neutrality efforts, these health impacts are projected to worsen, leading to increased mortality rates. Thus, prioritizing greenhouse gas mitigation is paramount for safeguarding public health and ensuring cleaner air.

Despite existing efforts, current US initiatives fall short, necessitating a holistic approach spanning policy, technology, and societal engagement. Local communities play a vital role in driving change through awareness and sustainable practices. At WPI, sustainability initiatives aim for carbon neutrality and energy efficiency, fostering a culture of sustainability among students. Leveraging data science can effectively track progress, while visualizing initiatives can engage the community. The Office of Sustainability is pivotal in leading these efforts. Our team developed a dedicated website to showcase our project's work and serve as a starting point for WPI’s Office of Sustainability.

Chapter 1: Introduction

The rapid modernization evident in the twenty-first century has raised major concerns about environmental impacts. As Hasan et al. (2024) puts it, the growing awareness of sustainability issues sheds light on significant environmental challenges with dire need for attention. Despite the worldwide imperative to reduce greenhouse gas and carbon emissions, there has been a noticeable increase in environmental pollution, primarily due to shifts in economic growth and energy consumption. For instance, the utilization of primary energy sources contributes to over 85% of CO_2 emissions, leading to adverse effects on both humans and animal species. According to a projection from the U.S. Energy Information Administration, if current technological trends and policies persist, global energy consumption is anticipated to surge by nearly 50% from 2020 levels to the year 2050. This remarkable increase in energy demand is attributed to rapid population growth, expanding economies, and higher living standards; with estimates suggesting a potential rise in global energy needs by a factor of 1.5-3 times by 2050 (Pham, Li, & Bui, 2023). The drastic increase in energy consumption places a higher demand on non-renewable energy sources, including coal, oil, and natural gas, which are widely recognized as the primary culprits behind climate change, resulting in the escalation of extreme weather events, sea-level rise, and the overall degradation of our planet's environment.

Discussions should then be focused on how to inform and persuade individuals to adopt sustainable practices and lifestyles. This entails promoting eco-centric mindsets and making relevant information more accessible. Promoting awareness and action fostered by data and climate communication allows communities to address the greater need for sustainability and environmental responsibility. Towards this end, information and communication technologies (ICT) have the potential to play a vital role. In the words of Chien et al. (2021), “The effective utilization of ICT sets out the foundations for emerging economies to imitate knowledge and information, improving connectivity worldwide." This view recognizes the importance of ICT in stimulating innovation which in turn creates healthy infrastructures, affordable clean energy, and eco-conscious individuals.

This project aims to integrate aspects of ICT into climate communication efforts to enhance data collection, visualization, public engagement, and mitigation efforts. As discussions center on the imperative for sustainable practices and the pivotal role of climate communication, universities such as Worcester Polytechnic Institute (WPI) are actively engaging in initiatives to mitigate their environmental impact. At WPI, the commitment to sustainability is evident, demonstrated by the institution's carbon commitment with Second Nature in 2022. As part of this commitment, WPI has begun to develop an extensive sustainability plan that outlines several initiatives WPI to reach carbon neutrality such as a 2020-2025 Sustainability Plan. While these initiatives themselves provide substantial benefits, we aim to enhance the initiatives by spreading climate communication and educating individuals about the importance of sustainable practices. Towards this end, the team has created a website to encompass the work done for this project as well as to demonstrate the effectiveness of a website in facilitating communication and information sharing regarding sustainability initiatives at WPI (refer to Appendix B). We hope that by incorporating ICT such as an online website into sustainability initiatives, we can amplify their impact by reaching wider audiences, fostering greater understanding, and inspiring action towards building a more sustainable future for all.

Chapter 2: Background

Greenhouse Gases (GHG)

Earth's atmosphere is composed of about 78 percent nitrogen, 21 percent oxygen, 0.9 percent argon, and 0.1 percent other gases (National Geographic Society, 2023). Carbon dioxide and methane are a part of the 0.1 percent of other gases. Greenhouse gases are responsible for trapping heat, and notable examples of these gases are nitrous oxide, methane, and carbon dioxide. Increased emissions of greenhouse gases contribute to elevated concentrations in the atmosphere, leading to a rise in Earth's temperature. These concentrations are gauged in parts per million, parts per billion, and parts per trillion. To put it into perspective, one part per million corresponds to roughly one drop of water dispersed into about 13 gallons of liquid, approximately equivalent to the fuel tank capacity of a compact car (EPA, 2023).

Emissions

Nitrous Oxide, or N_2O, poses a serious threat to our atmosphere. While it might not be as notorious as carbon dioxide or methane when it comes to global warming, it is a greenhouse gas that tends to fly under the radar. Also known as laughing gas, N_2O is the forgotten greenhouse gas contributing to climate change. It is often overlooked because it doesn't linger in the atmosphere as long as some other greenhouse gases. However, its warming potential renders it problematic for our earth's future. Pound for pound, N_2O is about 300 times more effective at trapping heat than carbon dioxide over a 20-year period (Brind'Amour & Lee, 2022). Many industrial activities contribute to the release of nitrous oxide into the air, with the main source being power plants.

Methane, is the more well-known gas in our atmospheric pollution, contributes major threats to both climate and health aspects. While it does not linger as long as carbon dioxide, this gas is an extremely potent gas—it may exit the atmosphere quickly, but its effects leave a lasting impact. Methane is more than 25 times more effective at trapping heat than carbon dioxide over a century. Short-term, it is over 80 times more potent, making it a powerful warming agent (US Environmental Protection Agency, 2023). The primary sources of these emissions are livestock digestion, rice cultivation, and the extraction and burning of fossil fuels all contribute to methane's grand entrance into our atmosphere.

Despite comprising only 0.04% of Earth's atmosphere, carbon dioxide plays a significant role in global warming (Fecht, 2021). Naturally present in the atmosphere as part of the Earth's carbon cycle, carbon dioxide (CO_2) is involved in the ongoing flow of carbon among the atmosphere, oceans, soil, plants, and animals. Unfortunately, human activities are disrupting this cycle by increasing atmospheric CO_2 levels and impacting the ability of natural sinks, like forests and soils, to absorb and retain CO_2 (NASA, 2024). While various natural sources contribute to CO_2 emissions, the substantial increase since the industrial revolution is primarily attributed to human-related activities. In 2021, carbon dioxide accounted for 79% of all U.S. greenhouse gas emissions resulting from human activities, as reported by the EPA. The main contributors to these emissions are transportation and the combustion of fossil fuels for energy (EPA, 2023).

Health Problems

There is more to the story when it comes to the long-term effects of methane and N_2O emissions. These gases are not just a climatic problem. Methane is a Volatile Organic Compound, and when it reacts in the atmosphere, it forms ground-level ozone—a major component of smog (American Lung Association, 2022). Long term exposure and breathing in this mix of pollutants can lead to respiratory problems, cardiovascular disease, pre-term birth and even cancer for humans prone to exposure (Environmental Defense Fund, 2023). Continuous exposure to methane emissions has been shown to increase oxidative stress, inflammation, and vascular dysfunction, which are all key risk factors for cardiovascular disease (Mendoza-Cano, et al., 2023). Individuals who live in a community with high methane emissions from coal fired power plants are at greater risk for developing heart disease.

Additionally, N_2O is harmful to human health, as long-term exposure to this gas can lead to infertility in humans (CDC, 2018). Methane and nitrous oxide are not just another greenhouse gas; they pose a dual threat, causing climate troubles and health problems, and it is crucial to recognize the importance of the effects on the atmosphere and our bodies.

While carbon dioxide is generally not considered directly harmful to human health, its impact on the environment, along with methane and nitrous oxide, can have consequences for human well-being. Despite CO_2 not being an air pollutant itself, its warming potential can negatively affect human health. The influence of factors like increased CO_2 emissions on climate change has notable implications for the prevalence and distribution of vector-borne diseases—illnesses transmitted by organisms acting as vectors, including mosquitoes, flies, and ticks. The ongoing shifts in climate, marked by daily, seasonal, or year-to-year variations, may lead to adaptations in vectors and pathogens, potentially expanding their geographical ranges. Consequently, this dynamic process poses health risks to human populations, as highlighted by the Centers for Disease Control and Prevention (CDC, 2020).

Power Plants in the United States

Power plants in the United States utilize a diverse array of energy sources, which can be categorized broadly as primary and secondary, renewable, and fossil fuels. Primary energy is produced from fossil fuels (such as petroleum, natural gas, and coal), nuclear power, and renewable energy sources. However, secondary energy is produced from primary sources, such as electricity. These energy sources are quantified using various units: liquid fuels are measured in barrels or gallons, natural gas in cubic feet, coal in short tons, and electricity in kilowatts and kilowatt-hours. In the United States, British thermal units (Btu), which quantify heat energy, are commonly used to compare different energy types. In 2022, the total primary energy consumption in the United States equated to 100.41 quadrillion Btu (quads) (EIA, 2023).

As energy consumption continues to rise, we can observe the harmful effects of power plant facilities on our environment. Over the past ten years, power plants have been responsible for over 75% of both methane and N_2O emissions, contributing significantly to the exacerbation of climate change (Stat from our Data). Methane and N_2O, commonly known as nitrous oxide or 'laughing gas,' are potent greenhouse gases that trap heat in the atmosphere at levels far higher than carbon dioxide. The unchecked emissions from power plants intensify the greenhouse effect and contribute to air pollution and other environmental issues. These emissions have been associated with deteriorating air quality and harmful effects on humans exposed to them. It is imperative that we address and mitigate the impact of power plant emissions to safeguard the health of our planet and its inhabitants.

We addressed this issue by investigating greenhouse gas emissions across various industries in the United States. Our approach involved analyzing a data set provided by the Environmental Protection Agency, that detailed the reported methane and nitrous oxide emissions nationwide. Our goal was to leverage this dataset, alongside supplementary data reporting the prevalence of various health problems in the United States, to unravel the complexity of the causes and effects of these harmful emissions and their potential implications for the well-being of our country. But delving deeper, we believed the best place to start was by first looking at how our local community at WPI was contributing.

Chapter 3: Sustainability at Worcester Polytechnic Institute

In confronting the immense challenges posed by the emissions of greenhouse gases from human activities and their implications on global warming, our focus shifts towards plans of action in our local community. Worcester Polytechnic Institute (WPI) can spearhead innovative sustainable operational technologies, enhance climate communication efforts, and serve as a model for other collegiate communities to undertake their own sustainability initiatives towards achieving carbon neutrality. WPI is actively fostering a culture of sustainability on campus and nurturing its local and regional community as a hub for sustainability innovation.

Recognizing the urgency of reducing carbon emissions, WPI has joined the Second Nature Group and is committed to achieving carbon neutrality expeditiously. In 2020, WPI initiated a five-year sustainability plan encompassing objectives such as establishing a dedicated office of sustainability, implementing a comprehensive lighting plan, and integrating sustainability projects into the curriculum. With this plan set to expire in 2025, WPI has recently entered a $45 million public-private partnership (P3) with Harrison Street, an investment management firm based in Chicago. Harrison Street's role in the partnership includes leasing, managing, operating, developing, and financing WPI's on-campus utility system, with a focus on sustainability initiatives.

In pursuit of carbon neutrality, the Office of Sustainability at WPI tracks and manages the campus' consumption of electricity, water, and gas, dating back to 2008. Despite the campus's expansion in terms of student population and physical footprint, WPI's estimated greenhouse gas emissions have decreased, emphasizing the impact of ongoing sustainability initiatives.

Collaborating with sustainability firm GreenerU, the Office of Sustainability has implemented a campus-wide LED lighting system to reduce electricity consumption. While GreenerU reports a substantial 53% reduction in energy usage in WPI's older buildings, such as Goddard Hall, since the installation of new lighting technology (GreenerU, 2023), it is important to note that this figure is part of a larger-scale initiative dating back to 2013-2014. This extensive project encompassed upgrades not only to lighting systems but also to lab equipment and ventilation mechanisms, resulting in the impressive energy savings cited. The current ongoing lighting effort, while impactful, is distinct from the comprehensive overhaul undertaken in previous years.

WPI’s Decreasing Electricity Usage

By analyzing the total electricity usage from 2008 to 2023, it is evident that these initiatives, like the lighting initiative, have been impactful in making WPI a more sustainable campus. As seen in figure 1, WPI’s collective electricity usage per student (FTE) has continued to decline, despite WPI’s growing campus. Within this same timeframe, WPI has physically expanded with the addition of new campus buildings including south village and unity hall, adding over 730,000 square feet to WPI’s footprint. With that being said, collaborative efforts with sustainability firm GreenerU have yielded impressive results, with significant reductions in energy usage observed in key campus buildings.

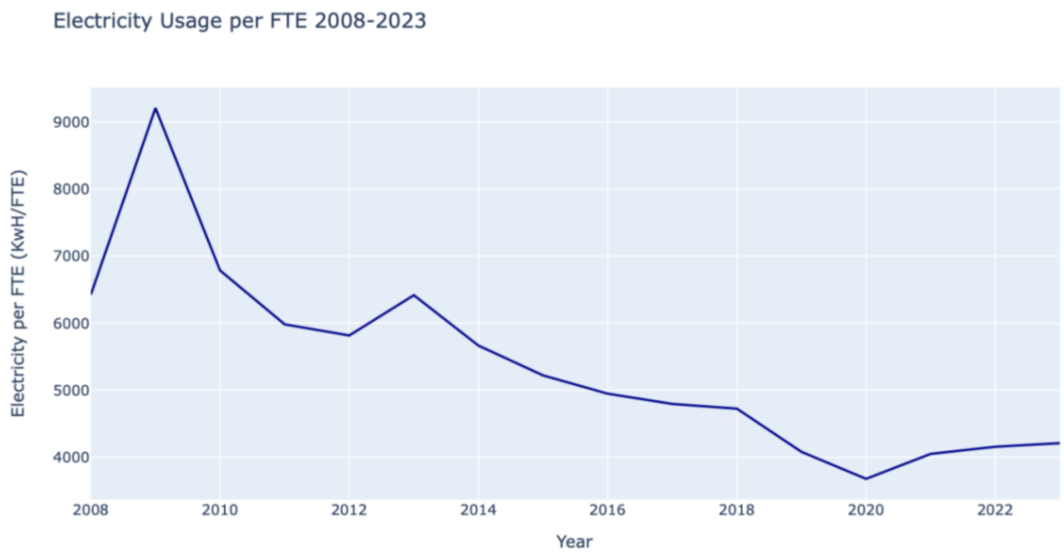

Figure 1: WPI's decreasing electricity usage per FTE from 2008-2023

WPI's Decreasing Greenhouse Gas Emissions

The Office of Sustainability also tracks the estimated greenhouse gas emissions from campus using UNH's SIMAP technology. "SIMAP® is a carbon and nitrogen-accounting platform that can track, analyze, and improve your campus-wide sustainability," (SIMAP, 2024). We can observe how these initiatives are directly impacting the university's emissions by analyzing the change in emissions over the same time span. From inspecting the total greenhouse gas emissions from WPI's entire campus from 2008-2023, it is evident that the initiatives and the decrease of the utility consumption around campus has already contributed to lowering WPI's overall greenhouse gas emissions.

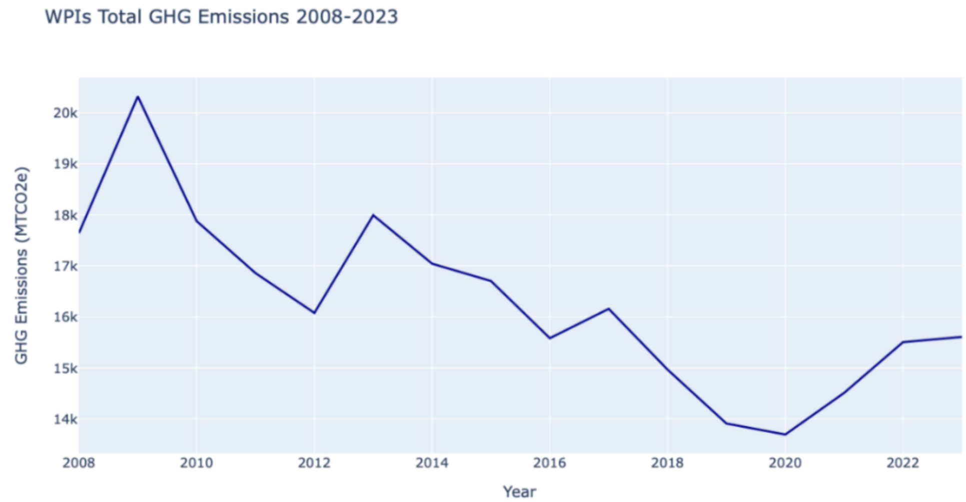

Figure 2: WPI's decreasing greenhouse gas emissions from 2008-2023

As seen in figure 2, the overall campus greenhouse gas emissions have trended downward, with peaks and dips, and increased emissions starting in 2020. To normalize the data so it reflects the growing student body, we can observe the total greenhouse gas emissions per student (FTE). In figure 3 below, it is observed that there is a much smoother downward trend in WPI's campus greenhouse gas emissions per student.

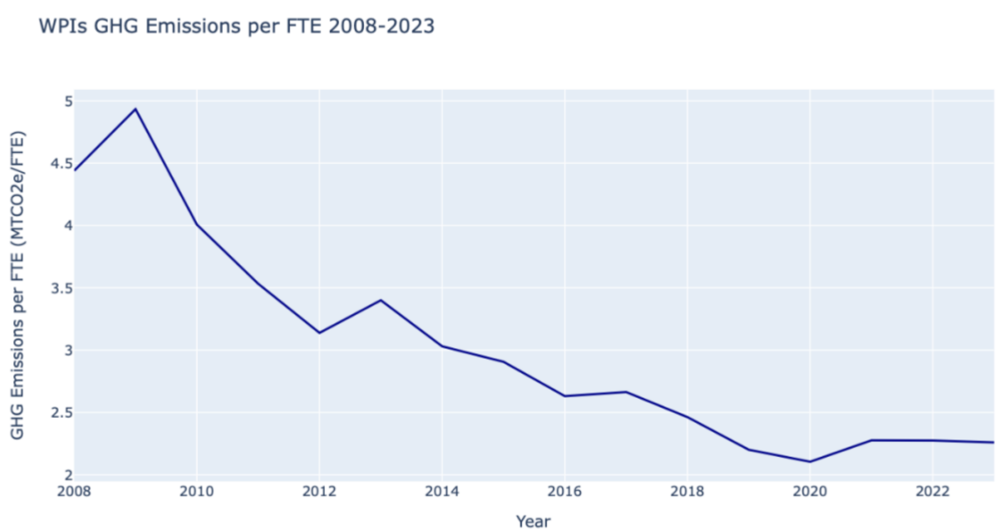

Figure 3: WPI's decreasing greenhouse gas emissions per FTE from 2008-2023

Analysis of WPI's electricity usage and greenhouse gas emissions over the years demonstrates a clear downward trend, showcasing the effectiveness of ongoing sustainability initiatives. The partnership with Harrison Street is expected to further accelerate progress towards a net-zero carbon footprint, as WPI leverages cutting-edge technologies and expertise to drive decarbonization efforts. To continue their progress, the Office of Sustainability continues to establish specific and measurable goals aligned with the overarching mission of carbon neutrality.

WPI's Decarbonization Plan

Leveraging the technologies and insights facilitated by the Harrison Street partnership, WPI will continue to make significant strides towards its goal of carbon neutrality. Currently, the engineering firms involved in this partnership like Cogen Power Technologies and Salas Obrien are taking over operations at WPI's on-campus power plant and drilling trial wells around WPI's campus. These energy conservation measures are projected to reduce WPI's annual greenhouse gas emissions by 45%, according to the office of sustainability partner Salas Obrien, who are developing an energy framework plan and investigating the feasibility and benefit of geothermal wells around campus. A roadmap of the first phase of this framework can be found in figure 4 below, which shows the estimated reductions in greenhouse gas emissions for each campus initiative.

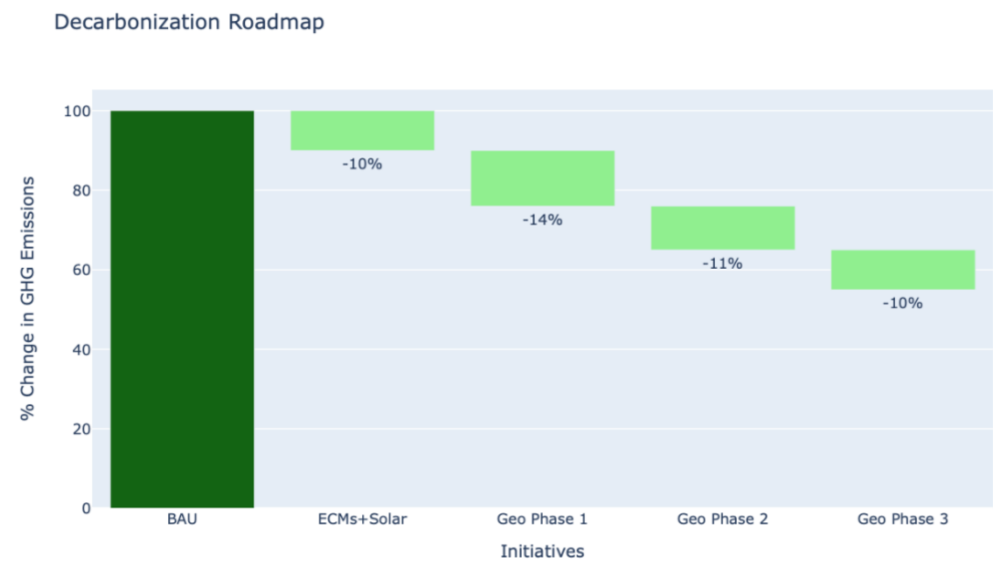

Figure 4: WPI's decarbonization roadmap for greenhouse gas emission reduction initiatives

According to the emissions data from the office of sustainability, and as seen in figure 5, a majority of the campus' greenhouse gas emissions come from the boilers around campus, mostly which reside in the campus power plant, called the Powerhouse. By implementing the changes outlined in the decarbonization plan, WPI can reduce the need and usage of the powerhouse and continue towards carbon neutrality by using cleaner sources of energy like geothermal wells.

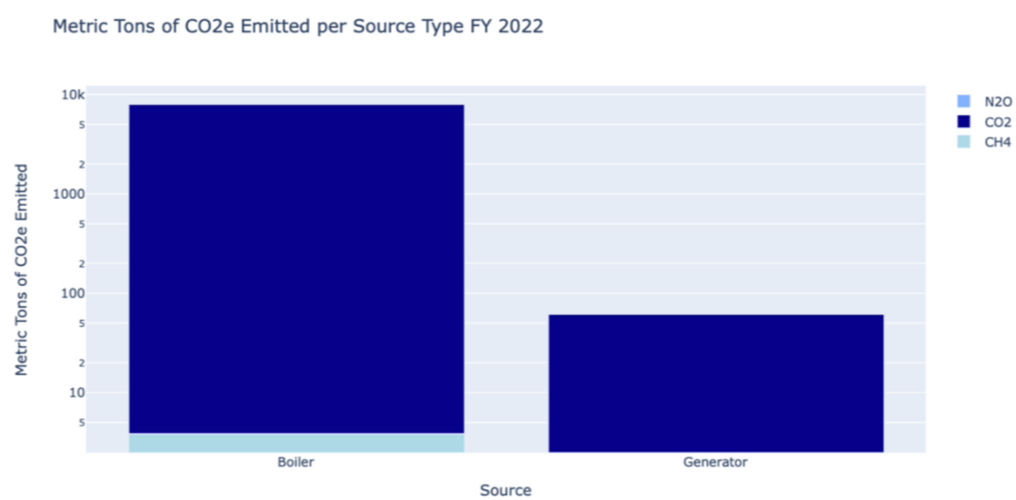

Figure 5: WPI's metric tons of CO2e emitted per source type in 2022 (log scale)

As WPI advances towards carbon neutrality, it is important that we improve climate communication around campus to spread the word and get students, faculty, and community members involved in the movement. These initiatives are already beginning to make tangible impact, as WPI continues to see decreases in greenhouse gas emissions around campus. With these changes and innovative advancements through sustainability research on campus, WPI can also inspire other campuses around Massachusetts and even the global university sector.

Chapter 4: Sustainability in Massachusetts

To analyze the broader context of sustainability initiatives in the community surrounding WPI, we can transition from the micro-level of our college campus to the macro-level of statewide efforts, to compare WPI's progress with other communities. While WPI's campus initiatives are crucial, we recognize that the scope of impact extends far beyond our immediate environment. Understanding our role within the larger framework of statewide sustainability efforts is imperative for fostering meaningful change. By examining the initiatives undertaken by institutions across Massachusetts, we can glean insights into effective strategies, identify areas for improvement, and collaborate on a collective journey towards a more sustainable future. Through this comparative analysis, we aim to assess how our institution measures up against its peers in Massachusetts, driving us towards a more comprehensive understanding of our collective impact and the path forward for sustainable progress.

As discovered through our analysis of emissions across the United States using U.S. fuel emissions data from the EPA, Massachusetts is very relatively low emitting state compared to other US states. This is demonstrated in figure 6, which illustrates the average methane emissions in each state from 2011-2021, with Massachusetts highlighted in dark blue.

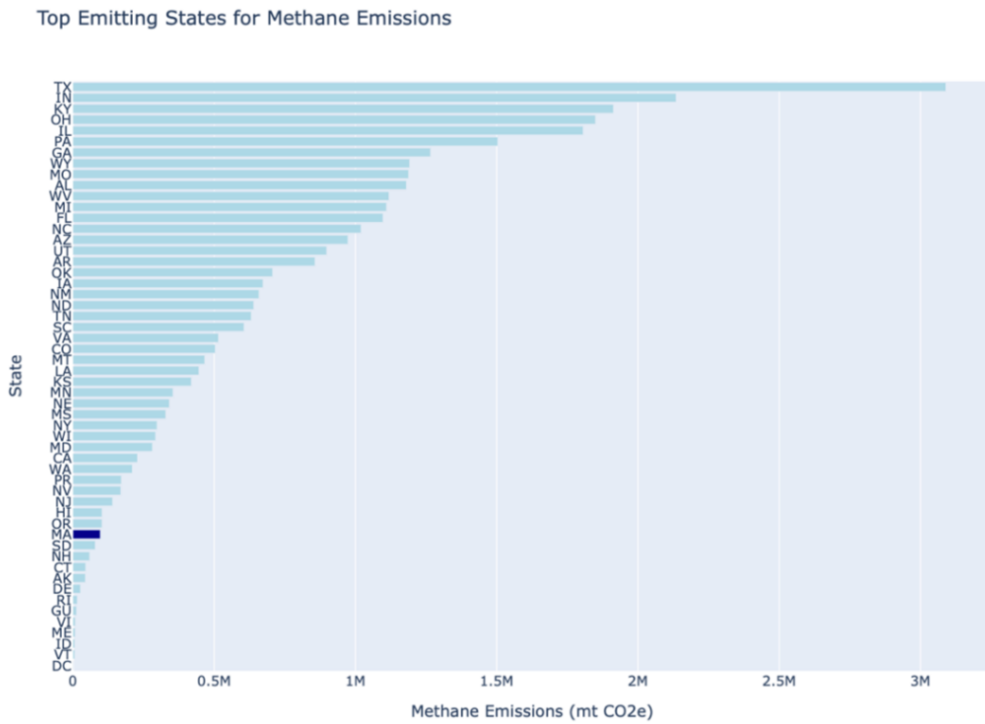

Figure 6: U.S. States by most methane emissions from 2011-2021

Despite Massachusetts' low emissions, it is crucial to identify avenues for collaborative action within our communities to reduce our carbon footprint and contribute to a more sustainable environment locally, nationally, and globally.

Schools around Massachusetts that are comparable to WPI in campus and student body size, such as Bentley, and Tufts, have similar carbon neutrality goals. Bentley University, located in Waltham, Massachusetts, has seen a 76% decrease in their campus greenhouse gas emissions since 2008, according to University of New Hampshire’s SIMAP public reporting platform. In their Sustainability Plan, Bentley notes their initiatives to reduce Greenhouse gas emissions like energy efficiency upgrades to reduce fossil fuel use. Bentley’s upgrades include things like transitioning to solar array power and water heating efficiency technologies. The university also focuses their plan on transportation and even reducing the emissions generated by their study abroad programs. Tufts University, located in the greater Boston area, also utilizes an interactive public dashboard to track and visualize their progress towards their sustainability goals. A screenshot of their public, interactive dashboard can be seen in figure 7, below.

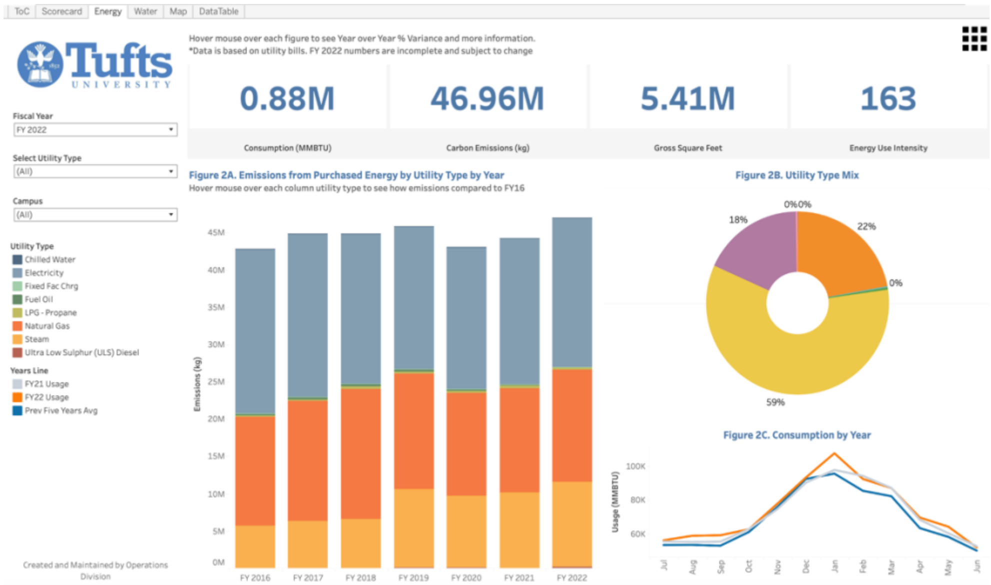

Figure 7: Screenshot of Tufts University's public sustainability dashboard

This allows for improved tracking and analysis of Tufts' initiatives and improves the climate communication within their community.

We aimed to compare WPI to other universities in Massachusetts. As mentioned before, WPI is a partner with GreenerU. Thus, we wanted to see if collaborating with a sustainability firm impacted a college's emissions. Communications were sent to other universities in the Massachusetts area that are partners with GreenerU. The University of Massachusetts at Amherst (UMA) agreed to participate in our project.

University of Massachusetts Amherst

We are appreciative of UMA for responding to our data inquiry request. The representative of their Sustainability Office, Mr. Ezra Small, the Campus Sustainability

Manager, met with our team and provided us with data and directed us to the publicly available data on their website. This data included source emissions data dating back to 2008. Sources included “Diesel for Fleet,” “Gasoline for Fleet,” “Purchased Electricity,” and “Natural Gas.” Essentially, this data gave us insight into where the emissions were coming from. He mentioned that we will see that the coal fuel type only had data from 2004 to 2008, as in 2008 UMA stopped using a coal fired power plant and switched to a natural gas plant to heat their campus.

Because UMA has a significantly larger student population, exceeding WPI's enrollment by over 20,000 students, it becomes imperative to analyze greenhouse gas emissions per student to effectively compare the success of sustainability efforts of both universities. Illustrated in Figure 8, while both UMA and WPI exhibit a downward trend in greenhouse gas emissions per student, UMA's emissions per student are greater those of WPI.

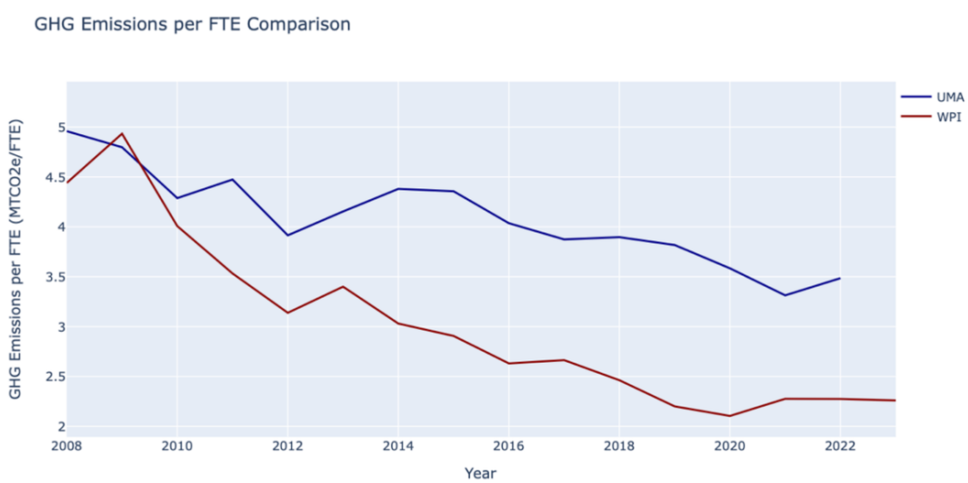

Figure 8: WPI and UMA GHG emissions per FTE

We were also directed to UMA’s emissions reports that are publicly available on the UMA Office of Sustainability website. The reports outlined UMA's roadmap of initiatives towards achieving carbon neutrality. For instance, in the realm of food and dining, UMA Dining backs the student division of the Food Recovery Network. This organization retrieves surplus food and distributes meals to a nearby homeless shelter throughout the academic year. Moreover, UMass Dining transforms excess food into fresh menu options and conducts informative events to promote awareness and reduce post-consumer waste (Rawson, 2023). By recovering surplus food and repurposing it into new menu items, UMA Dining minimizes the amount of food wasted, which in turn reduces greenhouse gas emissions associated with food decomposition in landfills.

Through the guidance of Mr. Small of UMA's Office of Sustainability, our team dove into the university's emissions data and sustainability initiatives, gaining insight into their environmental impact and commitment to sustainability. UMA's transparency in providing access to data and reports highlights their dedication to accountability and progress towards carbon neutrality. Through efforts like the Food Recovery Network, UMA Dining exemplifies proactive measures to reduce GHG emissions by minimizing food waste and repurposing surplus food. This partnership with UMA showcases the significance of collaboration between academic institutions and community stakeholders in driving sustainable change. Through developing such relationships and leveraging available resources and expertise, we can collectively address environmental issues and progress towards a more sustainable future.

Chapter 5: Power Plants

Even though Massachusetts is a low emitting state, we can transition to the broader context of the United States to gain a more comprehensive understanding of sustainability efforts and emissions on a national scale. Examining the broader landscape of emissions across the United States reveals a clearer picture of environmental impact, influenced by factors ranging from industrial activity to geographical features and population density. Each state contributes uniquely to the collective emissions profile, reflecting its economic structure, energy sources, and policy priorities. By zooming out to encompass the entirety of the U.S., we can uncover patterns in emissions intensity and identify ways our community initiatives could impact the nation.

With the wide range of human activities that contribute to these environmental issues around the country, energy consumption is a primary factor, with the power plant sector standing as a towering contributor to the greenhouse gas emissions in the United States. When examining United States emissions data, power plants emit significantly more methane and nitrous oxide emissions, two major culprits in the realm of harmful emissions, than other industries. In the broad topic of environmental responsibility, this chapter aims to investigate the complexities surrounding the environmental footprint of power plants.

Dataset Overview

Fuel Emissions (EPA)

This dataset was sourced from the US Environmental Protection Agency (EPA) that contains 276,961 data points. The file contains data collected by the Greenhouse Gas Reporting Program for 2010-2021 and was reported to the EPA by facilities as of 08/12/2022. The

Greenhouse Gas Reporting Program (GHGRP) collects Greenhouse Gas data from large emitting facilities, suppliers of fossil fuels and industrial gases that result in GHG emissions when used, and facilities that inject carbon dioxide underground (EPA, 2023). The emissions data is presented in units of metric tons of carbon dioxide equivalent using GWP's from IPCC's AR4.

Facility Id	FRS Id	Facility Name	City	State	Primary NAICS Code	Reporting	Industry Type (subparts)	Industry Type (sectors)	Unit Name	General Fuel Type	Specific Fuel Type
1012147		17Z Gas Plant - Chevro	McKittrick	CA	211130	2018	C,NN,W	Natural Gas and Na	CP-03.00	Natural Gas	Natural Gas (Weighted U.S. Average)
1012147		17Z Gas Plant - Chevro	McKittrick	CA	211130	2018	C,NN,W	Natural Gas and Na	CP-03.01	Natural Gas	Natural Gas (Weighted U.S. Average)
1012147		17Z Gas Plant - Chevro	McKittrick	CA	211130	2018	C,NN,W	Natural Gas and Na	CP-03.02	Natural Gas	Natural Gas (Weighted U.S. Average)
1012147		17Z Gas Plant - Chevro	McKittrick	CA	211130	2017	C,NN,W	Natural Gas and Na	CP-03.00	Natural Gas	Natural Gas (Weighted U.S. Average)
1012147		17Z Gas Plant - Chevro	McKittrick	CA	211112	2016	C,NN,W	Natural Gas and Na	CP-03.00	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2021	C,D	Power Plants	2301	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2021	C,D	Power Plants	2302	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2021	C,D	Power Plants	Heatec1	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2021	C,D	Power Plants	Heatec2	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2020	C,D	Power Plants	2301	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2020	C,D	Power Plants	2302	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2020	C,D	Power Plants	Heatec1	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2020	C,D	Power Plants	Heatec2	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2019	C,D	Power Plants	2301	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2019	C,D	Power Plants	2302	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2019	C,D	Power Plants	Heatec1	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2019	C,D	Power Plants	Heatec2	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2018	C,D	Power Plants	2301	Natural Gas	Natural Gas (Weighted U.S. Average)
1000112	11004380	23rd and 3rd	BROOKLY	NY	221112	2018	C,D	Power Plants	2302	Natural Gas	Natural Gas (Weighted U.S. Average)

Figure 9: EPA fuel emissions raw data screenshot

The datapoints contain the reported methane and nitrous oxide emissions by different facilities, with features such as facility ID, facility name, city, state, reporting year, and industry type. The original dataset contained 276,960 data points with 16 features. We created a correlation heat map of the remaining numeric values, seen in figure 10, to investigate any highly correlated columns within the data. First, we dropped columns ‘Other fuel name’ and ‘Blend fuel name’ because 99.53% and 99.82% of the data points were missing a value in these columns, respectively. We also dropped the ‘FRS ID’ column because it was associated with ‘facility ID’, and 10% of the values were missing. For similar reasons, we also deleted ‘industry type (subparts)’ because it was highly correlated with the column ‘industry type (sectors)’.

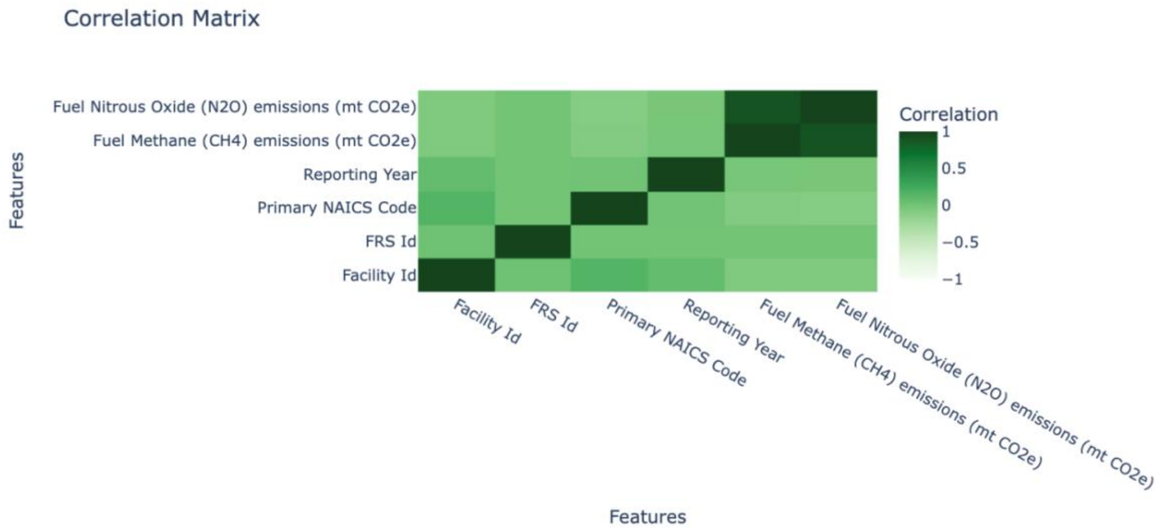

Figure 10: Correlation matrix of variables from EPA fuel emissions dataset

Based on this correlation heat map, methane and nitrous oxide emissions of a facility are highly correlated with each other, suggesting that a facility with high methane emissions would also have high nitrous oxide emissions. This is an interesting relationship that could be explored further. To investigate the relationship between the various coal fired power plant's methane and nitrous oxide emissions, we graphed the distribution using a scatter plot to identify any patterns.

As seen in figure 11, the distribution follows a very specific linear pattern. To consider why this may be, we observed if there was any pattern among the two linear relationships and the features in the dataset but found that there was no pattern.

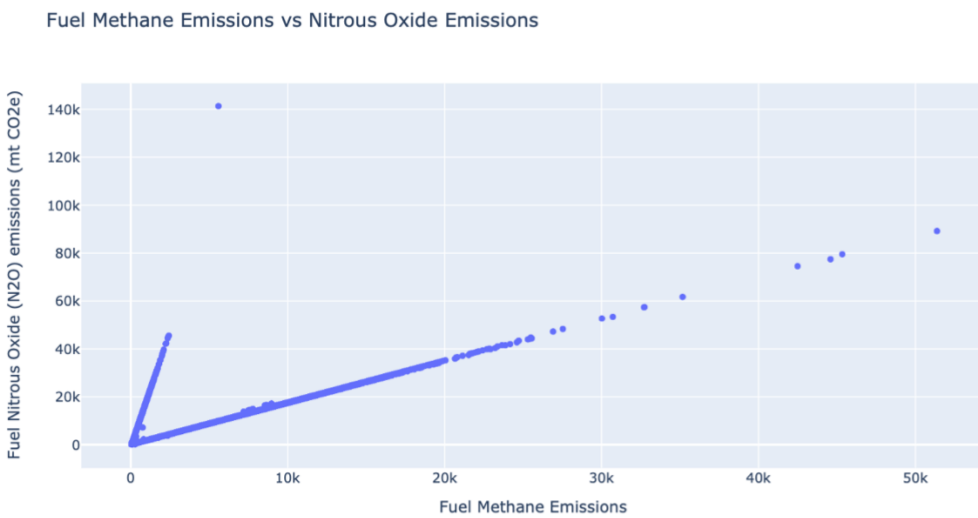

Figure 11: Distribution of Power Plants by Methane and Nitrous Oxide Emissions

We first checked for mutual exclusivity among the two distinct lines and found that there was a significant number of cities, states and facilities in both lines, and therefore there is no mutual exclusivity. This may be due to underlying differences in the various facilities' operational practices and procedures, which are not provided in the emissions data set. To explore this further, we performed K-Means clustering, as seen in figure 12, to try to cluster the data points into these two groups so we can observe why this distribution is the way it is.

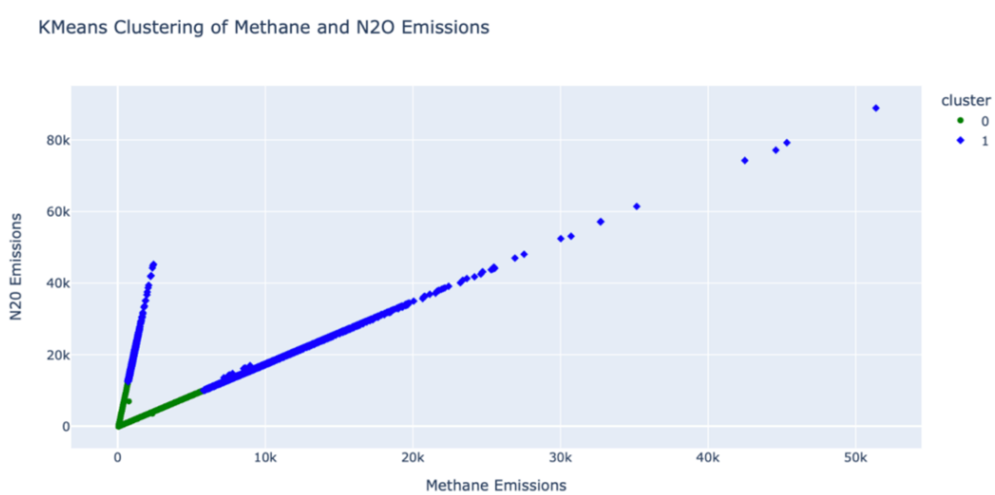

Figure 12: K-Means Clustering Plot of Power Plant Methane and Nitrous Oxide Emissions

As can be seen from figure 12, the clustering analysis was not successful in identifying the separate distributions. The clusters that the K-Means algorithm generated do not align with the two distribution patterns shown in the plot, suggesting that there is no pattern within the data to explain this relationship.

Through further exploratory data analysis, we discovered that the data points from the year 2010 were insignificant and unrepresentative of the emissions for that year, by looking at the total reported emissions over the time frame. As seen in figure 13 there is significantly less reported emissions in the year 2010.

Figure 13: Line Plot of Methane Emissions 2010-2021

We discovered that the data from 2010 made up less than 0.2% of the data, and therefore should not be considered in analysis, as it is highly likely that the data points are not representative of the entire year. After performing these data cleaning steps, there 276,328 data points remaining in the dataset. An example of the remaining data can be found in figure 14. We also performed min-max normalization on the numerical columns on the dataset, for some of our analysis.

Facility Id	Facility Name	City	State	Primary NA	Reporting	Industry Type (sector	Unit name	General Fuel	Specific Fuel Type	Fuel Methane (CH4)	Fuel Nitrous Oxide (N2O)
1012147	17Z Gas Plant -	McKittrick	CA	211130	2018	Natural Gas and Natu	CP-03.00	Natural Gas	Natural Gas (Weigh	1.5	1.788
1012147	17Z Gas Plant -	McKittrick	CA	211130	2018	Natural Gas and Natu	CP-03.01	Natural Gas	Natural Gas (Weigh	0	0
1012147	17Z Gas Plant -	McKittrick	CA	211130	2018	Natural Gas and Natu	CP-03.02	Natural Gas	Natural Gas (Weigh	0	0
1012147	17Z Gas Plant -	McKittrick	CA	211130	2017	Natural Gas and Natu	CP-03.00	Natural Gas	Natural Gas (Weigh	4.25	5.066
1012147	17Z Gas Plant -	McKittrick	CA	211112	2016	Natural Gas and Natu	CP-03.00	Natural Gas	Natural Gas (Weigh	4.75	5.662
1000112	23rd and 3rd	BROOKLYN	NY	221112	2021	Power Plants	2301	Natural Gas	Natural Gas (Weigh	11	11.92
1000112	23rd and 3rd	BROOKLYN	NY	221112	2021	Power Plants	2302	Natural Gas	Natural Gas (Weigh	10.5	11.92
1000112	23rd and 3rd	BROOKLYN	NY	221112	2021	Power Plants	Heatec1	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2021	Power Plants	Heatec2	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2020	Power Plants	2301	Natural Gas	Natural Gas (Weigh	13.5	14.9
1000112	23rd and 3rd	BROOKLYN	NY	221112	2020	Power Plants	2302	Natural Gas	Natural Gas (Weigh	18	20.86
1000112	23rd and 3rd	BROOKLYN	NY	221112	2020	Power Plants	Heatec1	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2020	Power Plants	Heatec2	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2019	Power Plants	2301	Natural Gas	Natural Gas (Weigh	11.5	14.9
1000112	23rd and 3rd	BROOKLYN	NY	221112	2019	Power Plants	2302	Natural Gas	Natural Gas (Weigh	9.25	11.92
1000112	23rd and 3rd	BROOKLYN	NY	221112	2019	Power Plants	Heatec1	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2019	Power Plants	Heatec2	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2018	Power Plants	2301	Natural Gas	Natural Gas (Weigh	19.25	23.84
1000112	23rd and 3rd	BROOKLYN	NY	221112	2018	Power Plants	2302	Natural Gas	Natural Gas (Weigh	13.5	14.9
1000112	23rd and 3rd	BROOKLYN	NY	221112	2018	Power Plants	Heatec1	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2018	Power Plants	Heatec2	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2017	Power Plants	2301	Natural Gas	Natural Gas (Weigh	14	17.88
1000112	23rd and 3rd	BROOKLYN	NY	221112	2017	Power Plants	2302	Natural Gas	Natural Gas (Weigh	10.25	11.92
1000112	23rd and 3rd	BROOKLYN	NY	221112	2017	Power Plants	Heatec1	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2017	Power Plants	Heatec2	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2016	Power Plants	2301	Natural Gas	Natural Gas (Weigh	16.25	20.86
1000112	23rd and 3rd	BROOKLYN	NY	221112	2016	Power Plants	2302	Natural Gas	Natural Gas (Weigh	14.75	17.88
1000112	23rd and 3rd	BROOKLYN	NY	221112	2016	Power Plants	Heatec1	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2016	Power Plants	Heatec2	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2015	Power Plants	2301	Natural Gas	Natural Gas (Weigh	16.25	20.86
1000112	23rd and 3rd	BROOKLYN	NY	221112	2015	Power Plants	2302	Natural Gas	Natural Gas (Weigh	14.75	17.88
1000112	23rd and 3rd	BROOKLYN	NY	221112	2015	Power Plants	Heatec1	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2015	Power Plants	Heatec2	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2014	Power Plants	2301	Natural Gas	Natural Gas (Weigh	8.75	11.92
1000112	23rd and 3rd	BROOKLYN	NY	221112	2014	Power Plants	2302	Natural Gas	Natural Gas (Weigh	10	11.92
1000112	23rd and 3rd	BROOKLYN	NY	221112	2014	Power Plants	Heatec1	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2014	Power Plants	Heatec2	Natural Gas	Natural Gas (Weigh	0	0
1000112	23rd and 3rd	BROOKLYN	NY	221112	2013	Power Plants	2301	Natural Gas	Natural Gas (Weigh	25.75	29.8

Figure 14: Remaining data after cleaning

Unit Emissions (EPA)

This dataset was also obtained through the EPA and was the sister set of the Fuel Emissions data. Features of this dataset include industry type, unit name, and biogenic unit CO_2 emissions, which is CO_2 produced by biological processes. The cleaning process for this dataset was similar to fuel emissions: we dropped columns that were missing a lot of values, along with all datapoints from 2010. Facility ID, FRS ID, Industry Type (subparts) were also removed.

Facility Id	FRS Id	Facility Name	City	State	Primary NAICS Code	Reporting	Industry Type (subparts)	Industry Type (sectors)	Unit Name	Unit Type	Unit Reporting Method	Unit Maximum Rated Heat Input (mmBTU/hr)	Unit CO2 emissions (no biogenic)
1012147		17Z Gas Plant - Chevron USA Inc.	McKittrick	CA	211130	2018	C,NN,W	Natural Gas and Natural Gas Liquids	CP-03.00	OCS (Other cor	Tier1/2/3	30	3304.
1012147		17Z Gas Plant - Chevron USA Inc.	McKittrick	CA	211130	2018	C,NN,W	Natural Gas and Natural Gas Liquids	CP-03.01	OCS (Other cor	Tier1/2/3	30	0.
1012147		17Z Gas Plant - Chevron USA Inc.	McKittrick	CA	211130	2018	C,NN,W	Natural Gas and Natural Gas Liquids	CP-03.02	OCS (Other cor	Tier1/2/3	30	17
1012147		17Z Gas Plant - Chevron USA Inc.	McKittrick	CA	211130	2017	C,NN,W	Natural Gas and Natural Gas Liquids	CP-03.00	OCS (Other cor	Tier1/2/3	30	9106.
1012147		17Z Gas Plant - Chevron USA Inc.	McKittrick	CA	211112	2016	C,NN,W	Natural Gas and Natural Gas Liquids	CP-03.00	OCS (Other cor	Tier1/2/3	30	9922.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2021	C,D	Power Plants	2301	Electricity Gene	Tier4, Alt-P75 c		23434.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2021	C,D	Power Plants	2302	Electricity Gene	Tier4, Alt-P75 c		22437.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2021	C,D	Power Plants	Heatec1	PRH (Process H	Tier1/2/3	7.4	84.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2021	C,D	Power Plants	Heatec2	PRH (Process H	Tier1/2/3	7.4	78.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2020	C,D	Power Plants	2301	Electricity Gene	Tier4, Alt-P75 c		25233.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2020	C,D	Power Plants	2302	Electricity Gene	Tier4, Alt-P75 c		35318.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2020	C,D	Power Plants	Heatec1	PRH (Process H	Tier1/2/3	7.4	90.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2020	C,D	Power Plants	Heatec2	PRH (Process H	Tier1/2/3	7.4	108.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2019	C,D	Power Plants	2301	Electricity Gene	Tier4, Alt-P75 c		24768.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2019	C,D	Power Plants	2302	Electricity Gene	Tier4, Alt-P75 c		19780.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2019	C,D	Power Plants	Heatec1	PRH (Process H	Tier1/2/3	7.4	30.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2019	C,D	Power Plants	Heatec2	PRH (Process H	Tier1/2/3	7.4	3
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2018	C,D	Power Plants	2301	Electricity Gene	Tier4, Alt-P75 c		41528.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2018	C,D	Power Plants	2302	Electricity Gene	Tier4, Alt-P75 c		28855.
1000112	110043809812	23rd and 3rd	BROOKLYI	NY	221112	2018	C,D	Power Plants	Heatec1	PRH (Process H	Tier1/2/3	7.4	140.

Figure 15: Unit Emissions data screenshot

Fuel & Unit Emissions

The emissions dataset contains the reported emissions per industry, which allows us to confirm that power plants produce a consequential number of emissions compared to other industries like the chemicals or waste industries. The extreme differences are visualized in figure 16 that plots the total methane and nitrous oxide emissions per industry over the 10-year span.

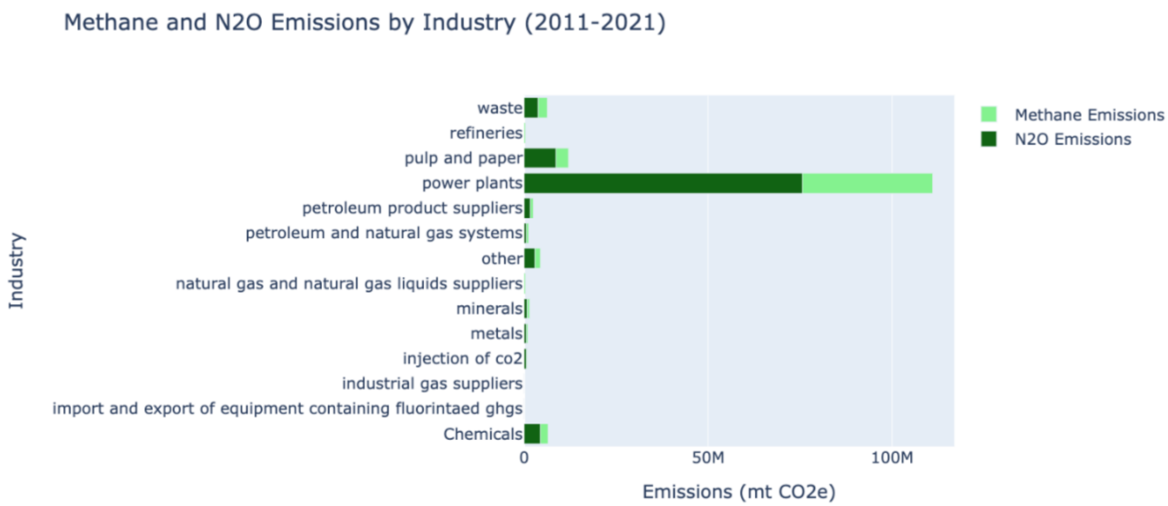

Figure 16: U.S. emissions from 2011-2021 by industry type

As mentioned before, carbon dioxide is an important GHG. Although CO_2 emissions arise from various natural sources, the rise in atmospheric CO_2 levels since the industrial revolution is primarily attributed to human-related emissions. Moreover, CO_2 concentrations are rising mostly because of the fossil fuels that people are burning for energy. According to the EPA, in 2021, carbon dioxide contributed to 79% of all U.S. greenhouse gas emissions from human activities (EPA, 2023). Based on figure 17, we see that the biogenic and non-biogenic CO_2 has decreased from 2011 to 2020, however, in 2020, there has been an increase.

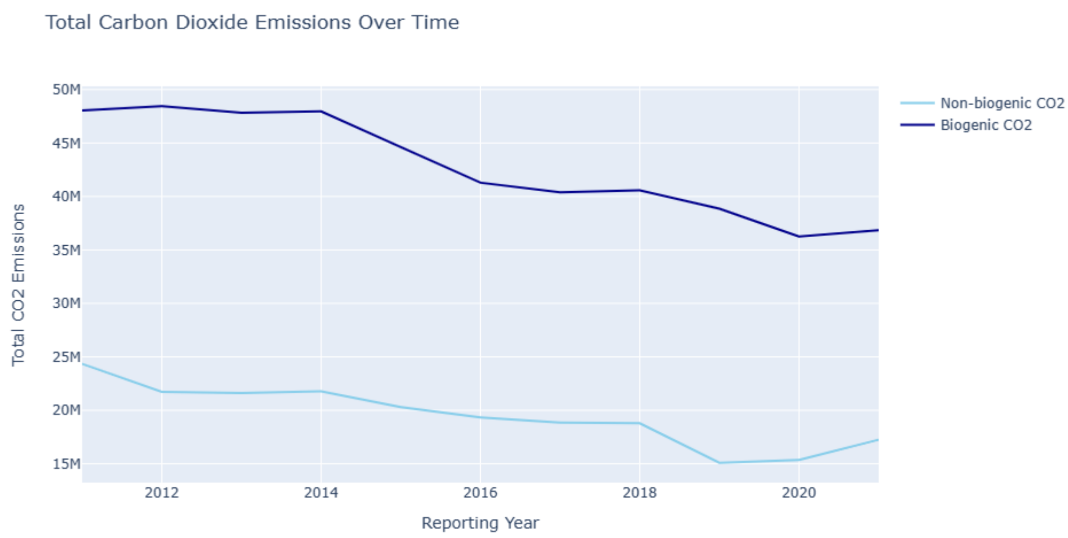

Figure 17: Unit Emissions of Carbon Dioxide from 2011-2021

Emissions from Coal Fired Power Plants

Within the power plant industry, there is a wide spectrum of facility types, ranging from traditional fossil fuel plants to solar and wind installations, each contributing to its unique environmental footprint and consequences. Among the many types of power plants, coal-fired power plants stand out significantly as a major concern due to their immense contributions to both methane and nitrous oxide emissions in the United States.

To investigate this further, we will utilize the emissions dataset's 'general fuel type' feature that labels how that facility is fueled. Through our data exploration and visualization, we found that coal fired power plants produce more methane and nitrous oxide emissions than the other plant fuel types, by a compelling amount. Figure 18 highlights the disproportionate contribution of coal-fired power plants to the overall greenhouse gas emissions in the U.S. from 2011-2021.

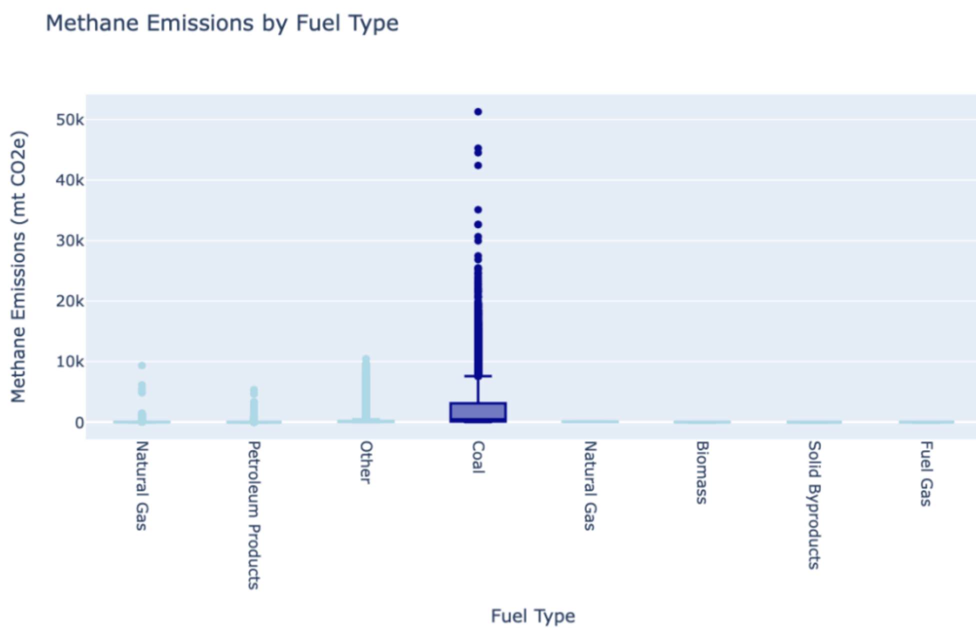

Figure 18: Power plant methane emissions by fuel type from 2011-2021

With most of the facilities' reported emissions in the emissions dataset coming from coal-fired power plants specifically, we continued to focus our analysis on the environmental impact of coal plants. This will allow us to delve deeper into the specific relationships surrounding human activity and the detrimental effects it has on the environment.

Most coal fired power plants in the United States were built and began operating in the 1970s and 1980's and have begun to retire due to competition from other generating sources that are generally cheaper and cleaner gases. (U.S. EIA, 2023) We can see the effects of these closures in the emissions dataset, by observing the change in emissions from coal-fired power plants over the given timeframe. Over the past 10 years, power plant emissions have generally declined overall with spikes in 2014 and 2021, as seen in figure 19.

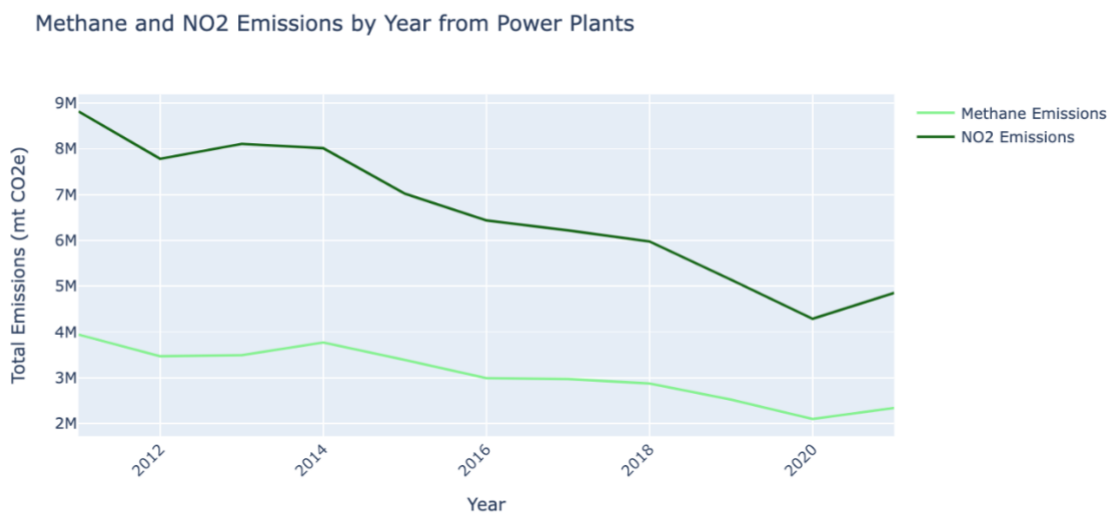

Figure 19: Power Plant Methane and Nitrous Oxide Emissions from 2011-2021

When looking at CO2 emissions for coal-fired power plants specifically, coal-fired power plants tend to emit more CO_2. When coal is burned, its carbon component reacts to the oxygen in the air to produce heat energy. CO_2 is a byproduct of this chemical process. Coal contains more carbon than oil or gas, and when we burn these fuels, the higher amount of carbon in coal reacts to form CO_2 (MIT Climate Portal Writing Team, 2022). Figure 20, which is below, shows the CO_2 emissions of power plants.

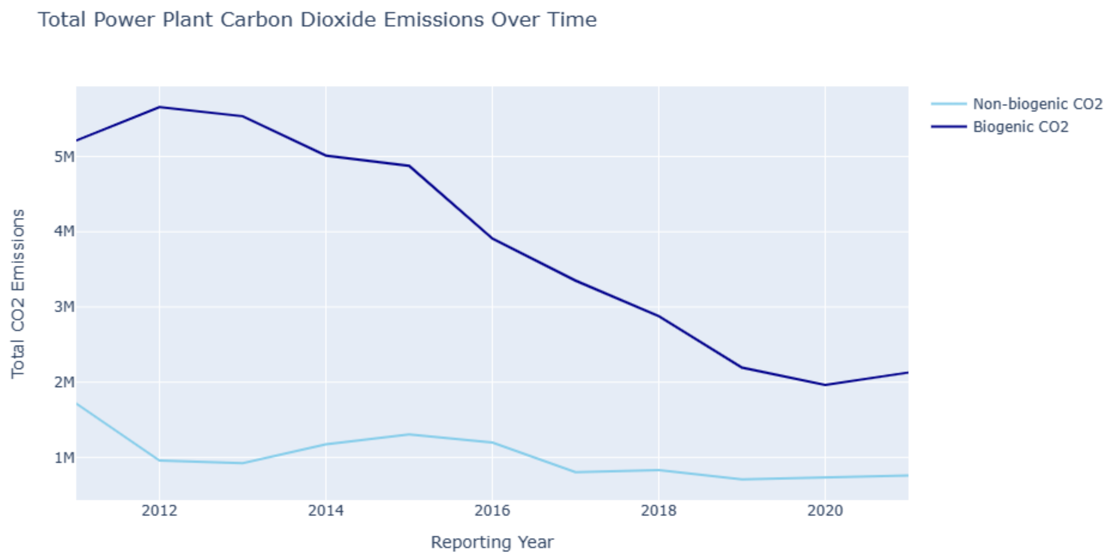

Figure 20: Power plant emissions of carbon dioxide (2011-2022)

From the figure, we see non-biogenic emissions initially have decreased, which corroborates the fact that coal fired power plants were being replaced with natural gas as natural gas has less climate pollution (Brady, 2023). However, emissions have gradually increased since 2013. According to the U.S. Government Accountability Office (GAO), the EPA reported power plant emissions have increased from 2020 to 2021, reflects growth in coal-fired power generation (GAO, 2022).

While coal plant closures represent a positive step toward reducing emissions, the lingering impact of these gases continues to grow. Greenhouse gases emitted during the combustion of fossil fuels, possess unique atmospheric characteristics that contribute to a prolonged environmental footprint. Unlike some pollutants that disperse rapidly, GHGs exhibit varied lifespans, ranging from a few years to thousands (EPA, 2023). As mentioned before, these gases significantly contribute to the greenhouse effect, trapping heat within the Earth's atmosphere. CO_2, the primary emission from coal combustion, can persist for centuries, influencing climate dynamics long after its release. Methane, with its heightened heat-trapping potential, has a shorter atmospheric lifetime but remains impactful for about a decade. Nitrous oxide, a potent greenhouse gas, endures for more than a century (Bailey & Callery, 2023).

Emissions Across the United States

When looking into coal-fired power plant emissions by state, Texas has a significant number of emissions compared to the other U.S. States. States like Illinois, Indiana, Ohio, Kentucky, as well as a few surrounding states also have a high amount of reported methane Emissions from coal fired power plants. This distribution can be seen below in figure 21.

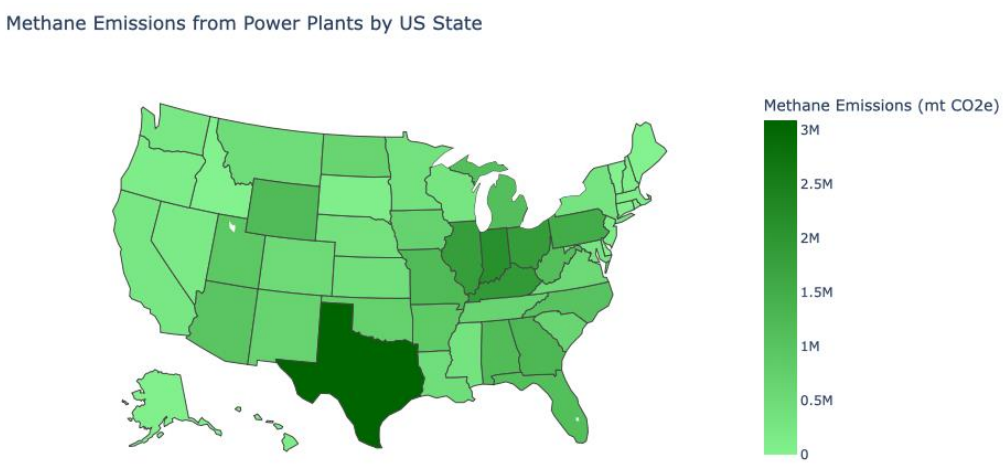

Figure 21: Power Plant methane emissions by U.S. state from 2011-2021

And as shown in figure 22 below, the distribution of N_2O emissions among the US states is like the methane emissions. Again, Texas has a significant number of emissions, and states Illinois, Indiana, Ohio, Kentucky, as well as a few surrounding states also have a high amount of reported N_2O Emissions from coal fired power plants.

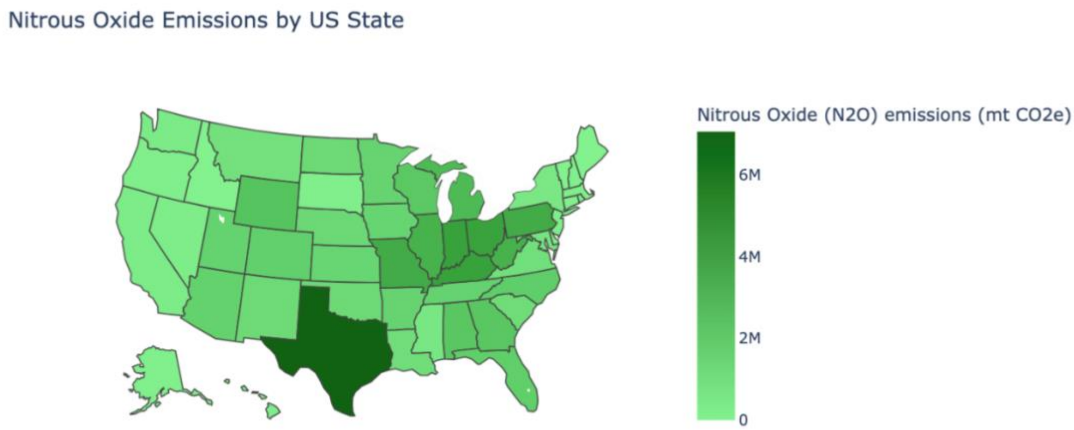

Figure 22: Power plant nitrous oxide emissions in the U.S. from 2011-2021

We then wanted to see which state emitted the most CO_2, and if its emission pattern mirrored that of methane and nitrous oxide. From figure 23, it's apparent that Iowa leads in CO2 emissions stemming from human activities, with notable resemblances in emission concentration around the Ohio and Pennsylvania regions.

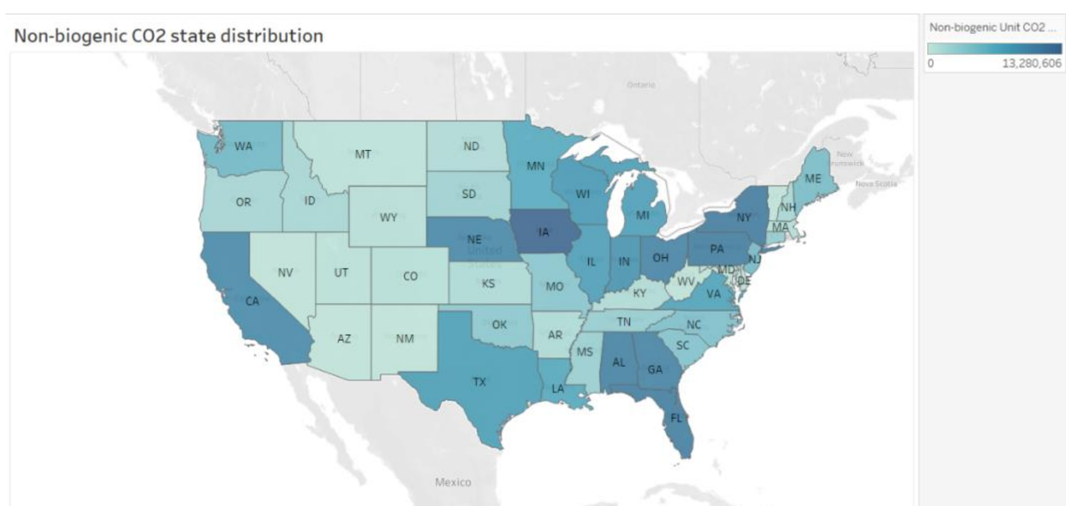

Figure 23: Non-biogenic CO2 state distribution

Iowa emits the most non-biogenic CO_2 followed by Florida, Nebraska, California, and New York. It is not surprising that California is one of the top states that emits high concentrations of CO_2 generated by human activity. As mentioned before, California has the most power plants in the United States. However, Iowa does not have many power plants, so why does it emit the most human generated CO_2? Iowa's carbon dioxide emissions are primarily from the electricity sector, which accounts for 71.7% of the state's total emissions (Choose Energy, 2023). Additionally, in 2021, Iowa experienced a 7.20 metric million tons carbon dioxide equivalent (MMtCO2e), which means the total warming effect of the additional greenhouse gases released is equivalent to the warming effect of emitting 7.20 million metric tons of carbon dioxide over 2020-2021 (Iowa Department of Natural Resources, 2022).

Because facilities can vary in size and therefore produce different amounts of greenhouse gas emissions, we investigated if states with high emissions tended to have a small number of large facilities with very high emissions, or many facilities spread out across the state. This can be seen in figure 24.

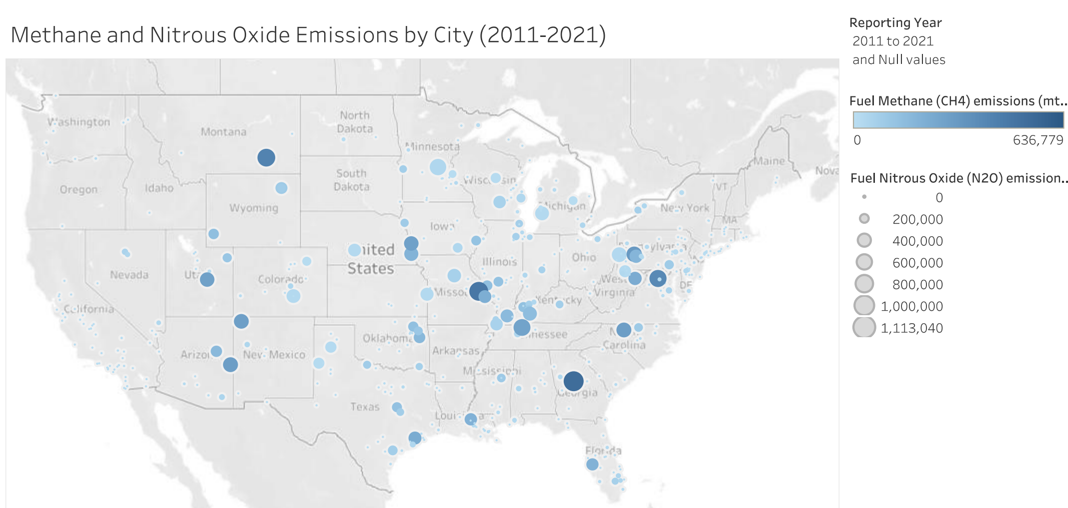

Figure 24: Methane and Nitrous Oxide Emissions by City (2011-2021)

This map shows the total reported methane emissions, represented by the darkness of the blue dot, and the total reported N_2O emissions, represented by the size of the dot. This provided new insight to us, as it shows that some cities are largely responsible for an entire state's emissions.

For example, Colstrip, Montana, and Juliette, Georgia all have a significant amount of both methane and N_2O emissions. While Texas, who has the highest statewide emissions, is made of many smaller and lighter dots, spread around the state.

In conclusion, the significant emissions of greenhouse gases from power plants present a pressing concern for our planet's climate stability. These emissions not only contribute substantially to the ongoing crisis of climate change but also exacerbate its far-reaching impacts on our environment, ecosystems, and communities worldwide. It is crucial to understand the severe impacts of these emissions, and it becomes increasingly evident that addressing the emissions from power plants is essential in mitigating the adverse effects and safeguarding the future of our planet. By acknowledging the role of power plant emissions in driving climate change, we take a crucial step towards adopting sustainable energy practices and fostering a healthier, more resilient world for generations to come.

Chapter 6: Climate Change

It becomes evident that the implications of these emissions extend far beyond the localized environmental impact. The greenhouse gases emitted, including methane and nitrous oxide, persist in Earth's atmosphere, exerting a profound influence on our planet's climate. These emissions are more than merely a statistic; they represent a significant driver of climate change. Their presence fuels the ongoing warming of our planet, contributing to environmental disruption and irreversible damage. As they persist in the earth's atmosphere, relentlessly fueling the ongoing warming of our planet and causing severe and irreversible damage to the earth as they contribute to environmental disruption. Their sustained presence in the atmosphere contributes significantly to global warming causing our exploration to naturally shift towards understanding the broader implications of these emissions on global climate patterns and the urgent need for sustainable solutions to mitigate their effects.

Global Atmospheric Concentrations of Greenhouse Gasses

To observe the effects that coal fired power plants have on the environment, specifically global warming, we utilized data from the global monitoring laboratory of the National Oceanic and Atmospheric Administration (NOAA) to analyze the global atmospheric concentrations of methane and nitrous oxide over time. The analysis shows that from 2000-2022, there has been a consistent upward trend in the concentration of both methane and nitrous oxide.

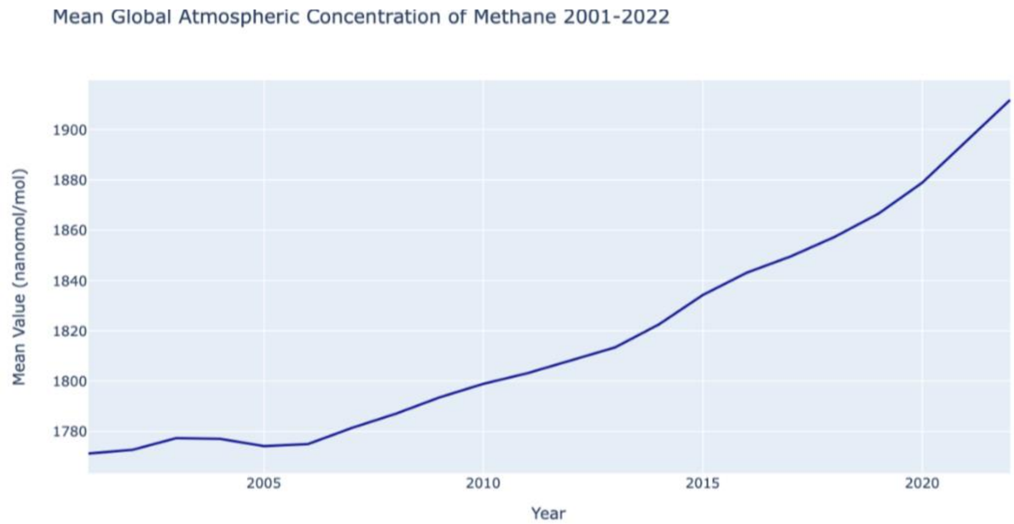

Figure 25: Mean global atmospheric concentration of methane (2001-2022)

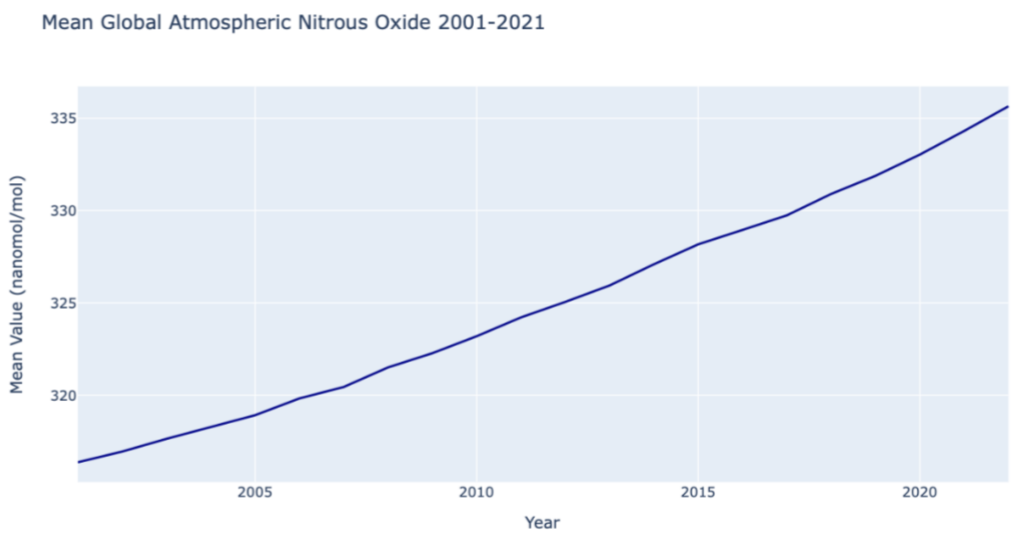

Figure 26: Mean global atmospheric nitrous oxide (2001-2021)

These upward trajectories highlight the undeniable impact of human activities, particularly the operations of coal-fired power plants, on our environment. This is important to note, because even as emissions from coal-fired power plants begin to decline, the concentrations of these gases persist and continue to increase, due to the long lifespan and powerful warming effects they have in our atmosphere. According to the EPA, “Historical measurements show that the current global atmospheric concentrations of CH4 and N_2O are unprecedented compared with the past 800,000 years," (EPA, 2023)

The combustion of fossil fuels, particularly coal, releases substantial amounts of methane and nitrous oxide into the atmosphere, perpetuating a cycle of environmental degradation. The repercussions extend beyond the immediate vicinity of these power plants, with the intense consequences felt globally as these gases intermingle and linger in the atmosphere. The extreme amounts of harmful emissions from coal plants greatly contribute to the greenhouse effect's intensification.

Increasing Surface Temperature in the United States

As methane and nitrous oxide, emanating largely from coal-fired power plants, intensify the greenhouse effect, the repercussions are vividly reflected in the upward trajectory of temperature records. Utilizing data from the IMF (collected by the FAO), we analyzed the average temperature change over time in the United States, as seen in figure 27. These temperature records indicate a pattern of warming that transcends natural climatic variation.

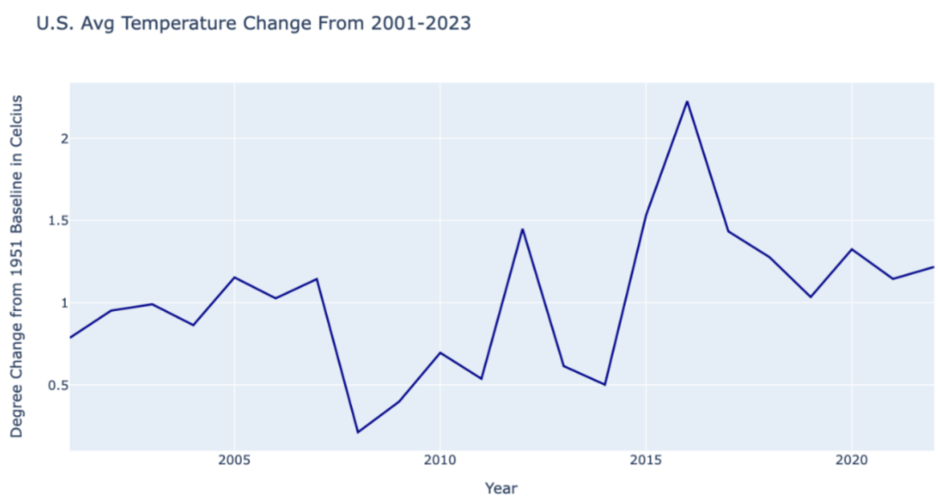

Figure 27: Average temperature change (2001-2023)

Although the relationship in the plot shows a nonlinear trend, we can utilize the surface temperature data, to zoom out and see how the temperature has changed over the past 60 years. By including these years in the analysis, starting before coal-fired power plants were widely used in the US, we can see there is a significant overall trend upwards in the average temperature since they have been implemented This broader trend in temperature is evident in figure 28.

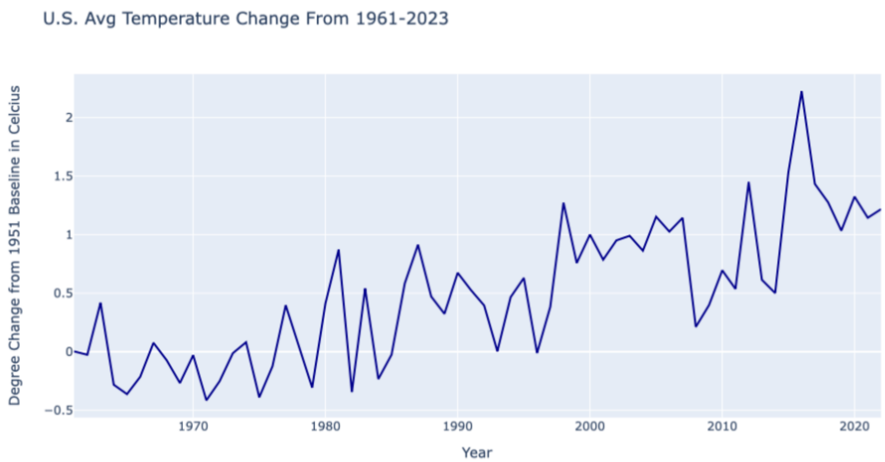

Figure 28: U.S. average temperature change (1961-2023)

Based on the White House's comprehensive long-term net-zero strategy unveiled in 2021, it is imperative that the United States achieves carbon neutrality by 2050 to avert a further 1.5-degree Celsius, or a 34.7 degree Fahrenheit, rise in Earth's surface temperature (The White House, 2021). Such an escalation would precipitate irreversible alterations to our planet's balance. This underscores the pressing need for all institutions and universities to intensify their sustainability endeavors, ultimately aiming for carbon neutrality. The persistent shifts in our climate, despite appearing gradual, will significantly affect our planet, posing multifaceted challenges to our society and ecosystems. These challenges threaten our security, well-being, and ultimately, our very existence.

Impacts

Besides the seemingly slight increase in temperature, climate change also causes a variety of extreme weather conditions and storms like flooding, hurricanes, drought, heatwaves, and wildfires (United Nations, n.d.) These dangerous conditions will continue to impact the environment in a magnitude of ways. From altering ecosystems and landscapes to disrupting vital natural processes, the ramifications of these extreme conditions reverberate throughout the interconnected web of Earth's systems, leaving a profound mark on both the natural world and human societies alike.

Agriculture stands as a major impact of the intricate relationship between weather patterns and climate dynamics. The reliance of agriculture on land and water exposes it to the multifaceted impacts of climate change. The shifting climate conditions disrupt traditional growing seasons, introducing uncertainties that challenge the stability of crop production. The increased frequency and intensity of wildfires further compound these challenges, posing a direct threat to farmlands (USGS, n.d.). Greenhouse gas emissions contribute to a dual impact on agriculture. Beyond the indirect effects of climate change, air pollution from these emissions can directly harm crops, plants, and forests. The intricate balance of ecosystems that sustain agriculture becomes increasingly vulnerable to disruptions, affecting the quality and quantity of essential food crops (EPA, 2023).

The repercussions of climate change extend beyond the fields, reaching into water resources vital for agricultural sustenance. Heavy precipitation, intensified by climate change, poses a threat to water quality. The runoff from these extreme weather events depletes soil nutrients, exacerbates agricultural runoff, and contributes to oxygen depletion in bodies of water.

The result is a perilous situation for aquatic life, including fish and shellfish species that depend on balanced ecosystems for survival (EPA, 2023).

Ecosystems also bear the brunt of climate change. Some species struggle to adapt to the rapidly changing conditions, leading to unprecedented expansions, reductions, and even extinctions. The delicate web of life unravels as key species face existential challenges. The increased frequency and intensity of natural disturbances, such as storms and wildfires, add to the complexity. These disturbances not only threaten the stability of ecosystems but also jeopardize carbon storage, with potential cascading impacts on climate dynamics and water sources (EPA, 2023).

These worsening conditions exacerbate factors driving poverty and displacement, as highlighted by the UN. Weather-related crises have led to more displacement than violence and conflict combined over the past decade. (UN, 2022) Such challenges exacerbate societal issues like poverty, hunger, and unequal access to natural resources. Extreme weather events caused by climate change tend to hit those least equipped to recover and adapt. (UN, 2022)

Communities Impacted

Studies are showing that poor and disadvantaged communities, particularly people of color, are exposed to higher levels of environmental pollution than other sectors of society (Truax, Bullard, & Club Books, 1994; Feldscher, 2022). We found an EPA graph on the number of power plants in different communities, specified by certain demographics (EPA, 2024). The data that the EPA used for the graph was publicly available, so we used the data to recreate the graph, which is seen in figure_. The dataset contained state level demographic data, as well as power plant emissions data for 2021. While the dataset had 3756 data entries and 309 features, there was a lot of missing data, so we were unable to do a thorough analysis. This data was helpful in identifying communities more vulnerable to environmental issues including pollution and emissions. For example, communities with a higher percentile of low-income, linguistically isolated, people of color, and individuals under age five, might be more vulnerable to pollution (EPA, 2023). (See figure 29)

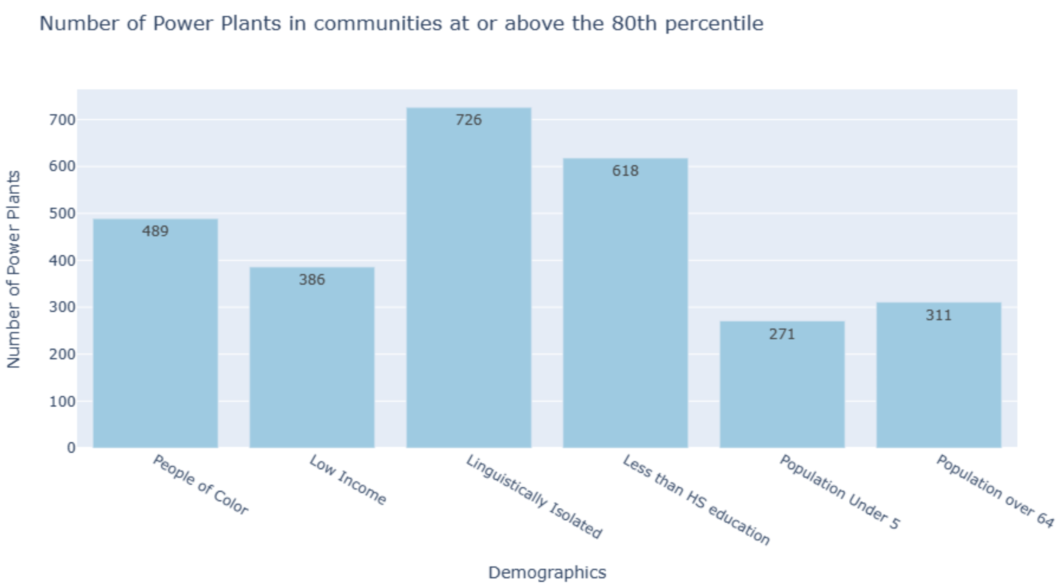

Figure 29: Number of power plant in communities at or above the 80th percentile

Tying back to the health problems caused by emissions, the people living in these types of communities, especially those who live near coal-fired power plants, have higher death rates and at earlier ages in tandem with increased risks of lung cancer and the respiratory and cardiovascular diseases. (Apt, 2017). Moreover, it is estimated that 1.37 million cases of lung cancer globally will be linked with coal-fired power plants in 2025 (Lin, et al., 2019). Furthermore, following the closures of power plants, there has been a six percent reduction in school absences within ten kilometers (or six miles) of the power plant and there has been a nine percent reduction in hospitalizations for asthma-related conditions in children (Marshall, 2023).

This reiterated that fact that climate change poses a direct threat to all humans, by causing and worsening various health conditions in humans, like asthma, COPD, and even heart disease.

In essence, the far-reaching consequences of climate change intertwine with the stability of agriculture, water resources, and ecosystems that we rely on. Recognizing that these impacts of climate change directly impact human health, the urgency to address it transcends environmental concerns alone. It becomes a critical necessity for safeguarding the sustainability of our connected natural systems and ensuring the well-being of current and future generations alike.

Chapter 7: Health Risks to Humans

Harmful greenhouse gas emissions also pose a direct threat to our physical health. While the repercussions of climate change reverberate throughout ecosystems and natural landscapes, the direct toll on human health is profound and immediate. As we confront the escalating impacts of industrial pollution and emissions from power plants, we must recognize the intricate interplay between environmental degradation and the many health risks facing populations worldwide. As was mentioned in Chapter 2, emissions are known to be the cause of many various health problems in humans (Yang & Omaye, 2009). Even so, power plants continue to produce air pollutants that degrade public health. Air pollutants contribute greatly to chronic diseases and mortality, including cardiovascular diseases, asthma, and chronic obstructive pulmonary diseases. To explore this further, we looked at two datasets representing chronic and cardiovascular diseases. In this chapter, we identify patterns between these diseases and emissions history.

Dataset Overview

U.S. Chronic Disease Indicators (CDI)

This dataset contains state-specific indicator data from the CDC between the years 2001-2021. To uniformly collect and report chronic disease information, the data was compiled from various sources such as death certificates, state registries, etc. It totals 1,048,576 datapoints on 124 different indicators defined by the CDC's Division of Population Health. We used this dataset to identify any increase in frequency of negative health conditions over the years.

Rates in Heart Disease and Stroke Mortality Among US Adults

This dataset is from the EPA and contains rates and trends in heart disease and stroke mortality. Specifically, this report presents county estimates of heart disease and stroke death rates in 2000-2019 by age group (ages 35–64 years, ages 65 years and older), race/ethnicity (non-Hispanic American Indian/Alaska Native, non-Hispanic Asian/Pacific Islander, non-Hispanic Black, Hispanic, non-Hispanic White), and sex (women, men). The rates and trends were estimated by the CDC National Vital Statistics System, using a Bayesian spatiotemporal model and a smoothed over space, time, and demographic group. Rates are age-standardized in 10-year age groups using the 2010 US population.

Impacts in the United States

Cardiovascular Disease

Cardiovascular disease is one of the leading causes of both death and disability in the United States (Yang & Omaye, 2009). Studies suggest that humans exposed to methane emissions have higher rates of oxidative stress, inflammation, and vascular dysfunction. All of which are key risk factors for cardiovascular disease (Mendoza-Cano, et al., 2023). To explore the direct effect power plants, have on humans specifically, we investigated similar trends of cardiovascular disease in the US and assessed any relationships.

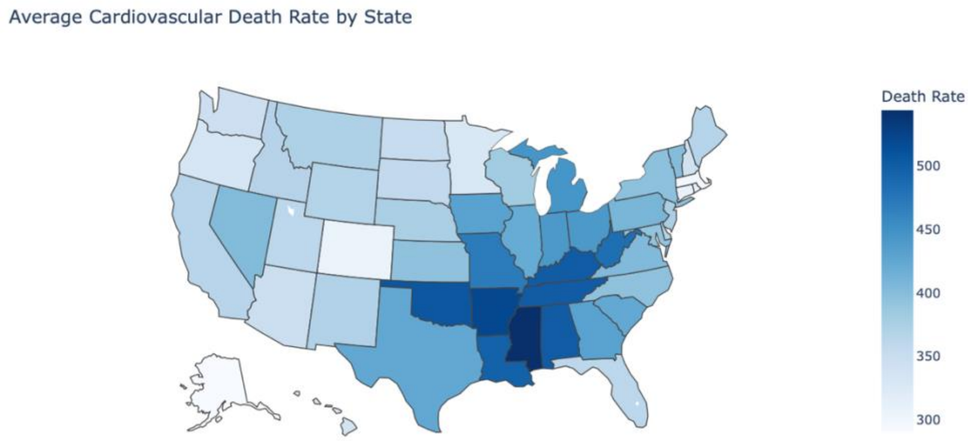

Figure 30: Average cardiovascular death rate by state

As can be seen in figure 30 representing heart disease related deaths, states like Texas and Georgia have the highest mortality rates for heart disease relation deaths among adults aged 35 years or older in the United States. By cross referencing this figure with the map of power plant locations in the United States, there appears to be a pattern between power plant density and heart disease mortality in adults. This supports the idea that individuals who live near coal fired power plants are more exposed to harmful methane and N_2O emissions which could cause such individuals a higher risk of developing health problems, like cardiovascular disease.

Asthma

Long term exposure to emissions can also aggravate respiratory diseases, especially asthma. A study in Birmingham, Alabama was conducted to determine if weekly variations in air pollution affected asthma hospitalizations between 1988 and 1990. This study found that smoke and air pollution, even at moderate levels, produced significant health effects and could be associated with more hospital admissions (Yang, 2009). With asthma being such a prevalent disease among Americans, air pollution should be reduced to prevent more widespread morbidity and mortality.

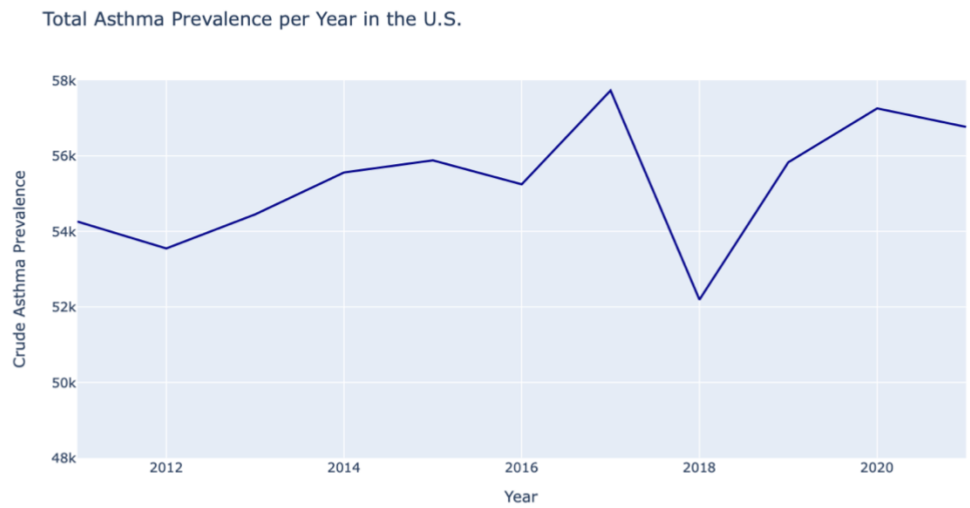

Figure 31: Total asthma prevalence per year in the U.S.

Figure 31 seen above represents the percentage of adults reported to have had asthma over the age of 18 from 2011-2021. A steady increase in this metric can be observed over this time frame. In 2011, the percentage of adults with asthma was 9.8408% while in 2021, the number was 10.6493%. This difference may not seem significant, however, when considering that the population of adults in the U.S. over the age of 18 in 2021 was 259,219,518, which means these numbers account for an increase of roughly 2 million people (Annie E. Casey Foundation, 2023).

Chronic Obstructive Pulmonary Disease

Chronic obstructive pulmonary disease (COPD) is a group of various lung diseases that obstruct airflow, making it difficult to breathe. Oxidative stress caused by air pollutants are known to be common initiators and promoters of damage produced by COPD. Studies have shown that in Sydney, Vancouver, Reno, and other U.S. cities, hospital admissions for COPD were reported and was found to be associated with air pollution (Yang & Omaye, 2009).

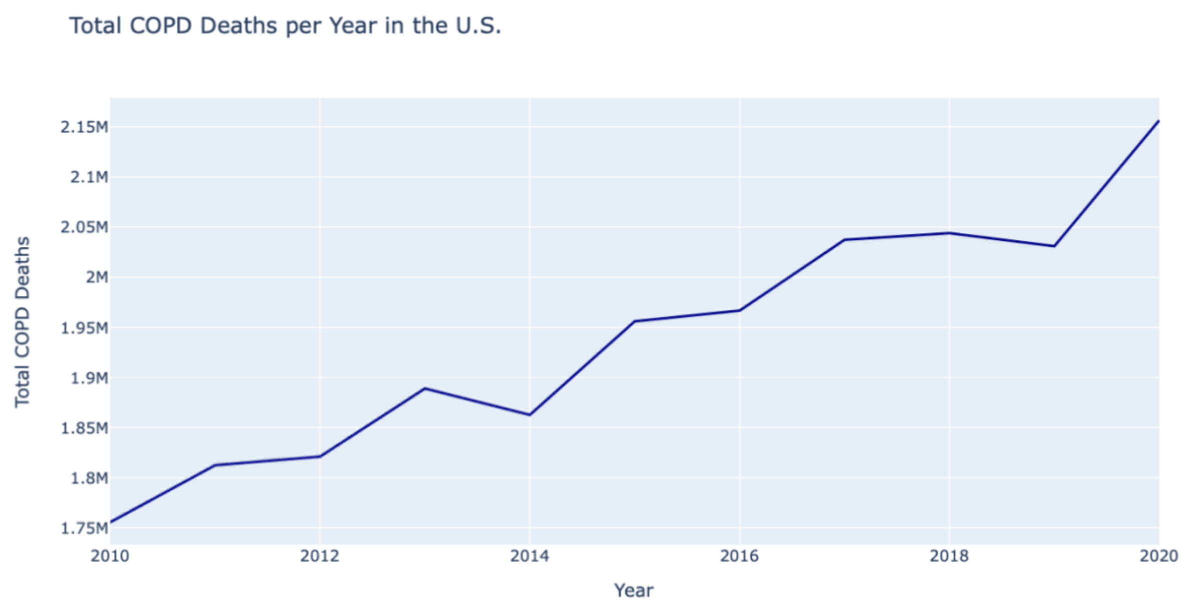

Figure 32: Total U.S. COPD deaths per year

Figure 32 visualizes the average deaths per 100,000 population among adults aged 45 years or older with chronic obstructive pulmonary disease (COPD) as the underlying or contributing cause from 2010-2020. It is clear the graph depicts a noticeable upward trend over the specified period. This alarming increase in mortality rates associated with COPD may be indicative of a potential association with declining air quality during the same period. Further investigation into environmental factors and air pollutant levels could provide valuable insights into the observed health outcomes.

Recognizing the impact that GHG emissions have had on human lives, it becomes imperative to implement sustainable practices and regulations to mitigate their effects. From this analysis, the issue at hand becomes a public health crisis, necessitating urgent action to address the consequences of our emissions. By enforcing stricter policies, the well-being of both current and future generations can be safeguarded.

Chapter 8: U.S. Policies and Regulations

When considering the direct threat to humanity, it becomes evident that immediate action is crucial to mitigate these threats to public well-being. By understanding the complex interplay between human activities, emissions, and the impacts of climate change, we can inform targeted interventions and policies to mitigate the environmental footprint and foster a sustainable future for generations to come.

In this section, we will discuss three pivotal initiatives that significantly influence environmental policies in the United States: The Clean Air Act, the Clean Power Plan, and the Affordable Clean Energy (ACE) Rule. These initiatives are essential components of the nation's commitment to addressing climate change, mitigating air pollution, and fostering sustainable energy practices. Understanding the intricacies of these measures is crucial for navigating the complex landscape of environmental policy, as they play a vital role in shaping the future of public health, energy production, and overall environmental well-being. Then, we will discuss a couple of potential national regulations that could be implemented to curb emissions.

Current Energy Consumption and Production Regulations and Efforts

Clean Air Act

The Clean Air Act stands as a comprehensive federal law that plays a pivotal role in regulating air emissions from both stationary and mobile sources. Administered by the Environmental Protection Agency (EPA), the Act encompasses a multifaceted approach to air quality management. One of its primary objectives is the establishment of standards for ambient air quality, aimed at reducing outdoor concentrations of pollutants responsible for smog, haze, and acid rain (EPA, 2007). By defining and enforcing these standards, the legislation seeks to safeguard public health and the environment from the detrimental effects of air pollution. In addition to regulating general air quality, the Clean Air Act addresses the emissions of hazardous air pollutants. Special attention is given to substances known or suspected to cause cancer, with stringent regulations in place to limit their release into the atmosphere (EPA, 2007). This aspect of the Act underscores a commitment to minimizing the health risks associated with exposure to toxic air contaminants.

The legislation also places emphasis on the protection of Earth's ozone layer. Specific provisions within the Clean Air Act are dedicated to phasing out the production and use of chemicals that pose a threat to the ozone layer. Recognizing the critical role of the ozone layer in maintaining habitable conditions on our planet, these measures contribute to global environmental preservation (Ritchie, 2023). As a dynamic and evolving piece of legislation, the Clean Air Act reflects the ongoing commitment of the United States to address emerging challenges related to air quality and environmental protection.

Clean Power Plan

The Clean Power Plan, initiated during the Obama administration, represented a significant effort to curtail carbon dioxide emissions from existing power plants. This groundbreaking initiative established state-specific targets for emission reduction and actively promoted the adoption of renewable energy sources (Office of the Press Secretary, 2015). Despite its laudable goals, the plan encountered legal challenges and ultimately faced repeal under the Trump administration, which implemented a much weaker rule (Irfan, 2019).

Notably, the Clean Power Plan was the nation’s first legislature regulating power plants. Its primary goal was to significantly reduce carbon pollution from power plants, addressing both climate change and minimizing pollutants linked to the adverse effects of soot and smog on public health. Simultaneously, the plan aimed to stimulate innovation, development, and deployment within the clean energy sector, laying a foundation for a comprehensive, long-term strategy to address the climate crisis. The plan's strength lay in its provision of considerable flexibility and time for states and utilities to achieve the mandated pollution reductions. This approach aimed to optimize the balance between environmental protection and the maintenance of a reliable and affordable electricity supply for consumers and businesses. By allowing for adaptation to regional variations and unique circumstances, the Clean Power Plan sought to create a pragmatic framework for sustainable progress.

Crucially, the initiative recognized the enduring role of fossil fuels in America's energy landscape. Instead of eliminating them entirely, the Clean Power Plan aimed to enhance the cleanliness and efficiency of power plants using fossil fuels. Concurrently, it sought to expand capacity for zero- and low-emission power sources, promoting a diversified and resilient national energy portfolio (EPA, n.d.).

In summary, the Clean Power Plan was a forward-looking and comprehensive strategy that endeavored to balance the imperative of reducing emissions with the practicalities of maintaining a robust and adaptable energy sector. While its fate may have shifted with changing administrations, the plan's vision and principles remain influential in shaping ongoing discussions about the intersection of energy policy, environmental stewardship, and public health.

Affordable Clean Energy Rule (ACE)

Implemented during the Trump administration, the Affordable Clean Energy (ACE) Rule aimed to guide states in developing their plans to enhance the efficiency of existing coal-fired power plants, diverging from the approach of setting specific emission reduction targets. In contrast to the Clean Power Plan, which established statewide emission reduction goals, the ACE rule focused on the individual level of power plants, striving to stimulate efficiency enhancements at this operational scale. Differing from the broader scope of the Clean Power Plan, the ACE rule primarily addressed emissions from power plants and placed less emphasis on broader strategies to promote renewable energy. This shift in focus made the ACE rule narrower in its regulatory scope (EPA, 2023).

The ACE rule triggered controversy, as critics argued that it fell short in adequately addressing climate change and raised concerns about potentially weaker emissions standards for power plants (Harvard T.H. Chan School of Public Health, 2019; Irfan, 2019). Supporters, however, maintained that the rule offered increased flexibility to states and industries. In 2022, the D.C. Circuit ruled that the ACE Rule must be vacated as the Trump administration incorrectly interpreted Section 111(d) of the Clean Air Act, which deals with regulating emissions from existing sources (Detterman, Christensen, & Pilchen, 2021; Environmental Defense Fund, 2014).

In summary, the Clean Air Act, Clean Power Plan, and Affordable Clean Energy Rule represent critical milestones in the United States' effort to combat climate and protect public health. These initiatives emphasize the nation's commitment to environmental stewardship and sustainable energy practices. However, it is fundamental to understand the fight against climate change and greenhouse gas emissions necessitates collective action at all levels, spanning from governmental policy making to individual behavioral changes. Although national regulations establish important standards and provide a framework for action, meaningful progress is only driven by the combination of efforts of the government, industries, communities, and people.

Grassroots movements play a vital role in complementing national policies. Supporting renewable energy projects, advocating for clean air and water, and engaging in sustainable practices in our daily lives are tangible ways to contribute to a healthier planet. Institutions like WPI epitomize the power of education and research in advancing sustainable solutions. Through fostering innovation and collaboration, academic systems can push progress towards an eco-friendlier future.

Chapter 9: Contributions and Conclusions

The long-lasting nature of greenhouse gases (CH4, N_2O, CO_2) means that their cumulative impact continues to influence Earth's climate even after emission sources are reduced. This underscores the importance of sustained efforts to transition to cleaner energy sources, enhance energy efficiency, and implement strategies for carbon capture and sequestration to address both current and historical emissions. From earlier analysis, there was found to be an increasing trend of morbidity across a range of chronic health issues from around 2010-2021, potentially in relation to exposure to pollutants persisting in the atmosphere. If carbon neutrality efforts are not expedited sooner, these health impacts are projected to worsen, leading to an increase in the number of deaths each year. Thus, alongside environmental concerns, prioritizing action towards mitigating greenhouse gas emissions is crucial for safeguarding public health and ensuring clean, healthier air.

It has been made evident that current efforts to reduce greenhouse gas emissions in the United States are not yet sufficient in countering their adverse impacts. As the nation grapples with the imperative to mitigate climate change and transition towards a more sustainable future, it becomes essential to integrate diverse measures that span policy, technology, and societal engagement. While it is difficult to implement and enforce nationwide policies, it is possible to effect change within local communities. By fostering awareness and promoting sustainable practices through climate communication, individuals and communities can play a pivotal role in collectively reducing carbon footprints and cultivating a more environmentally conscious society.

Contributions

Within WPI, a range of successful sustainability initiatives has emerged, aiming to reach carbon neutrality and enhance energy efficiency. These endeavors align with WPI's broader sustainability objectives, such as equipping graduates with the mindset and skills necessary to devise sustainable solutions to global challenges. Raising awareness and instilling eco-friendly values in students could foster a culture of sustainability and create the next generation of environmentally conscious leaders. However, despite these efforts, achieving this goal remains elusive. One explanation for which could be attributable to lack of climate communication. During this project, we found it challenging to access data and information regarding WPI's sustainability initiatives. To address this issue, leveraging data science (DS) techniques for progress tracking and analytics could prove instrumental. By implementing DS methodologies, WPI can gain insights into the effectiveness of current sustainability initiatives, identify areas for improvement, and track progress towards carbon neutrality more effectively. Additionally, utilizing engaging visualizations to showcase these initiatives around campus can help facilitate engagement with sustainable practices among the campus community. The Office of Sustainability can play a pivotal role in spearheading these efforts by actively engaging students, faculty, and staff in sustainability-related activities and initiatives. Based on our challenges encountered during the research process, we recommend implementing these strategies to overcome barriers to information access and foster a culture of sustainability at WPI.

Additionally, WPI could benefit from implementing a centralized platform for sustainability-related matters in the form of a website. This platform would enhance data accessibility, highlight the importance of sustainability on campus, and establish WPI as a hub for sustainable innovations. As a part of this project, the team has developed a website to showcase the project’s work and to demonstrate the usefulness of a website for promoting climate communication and raising awareness of sustainability initiatives (figure 33).

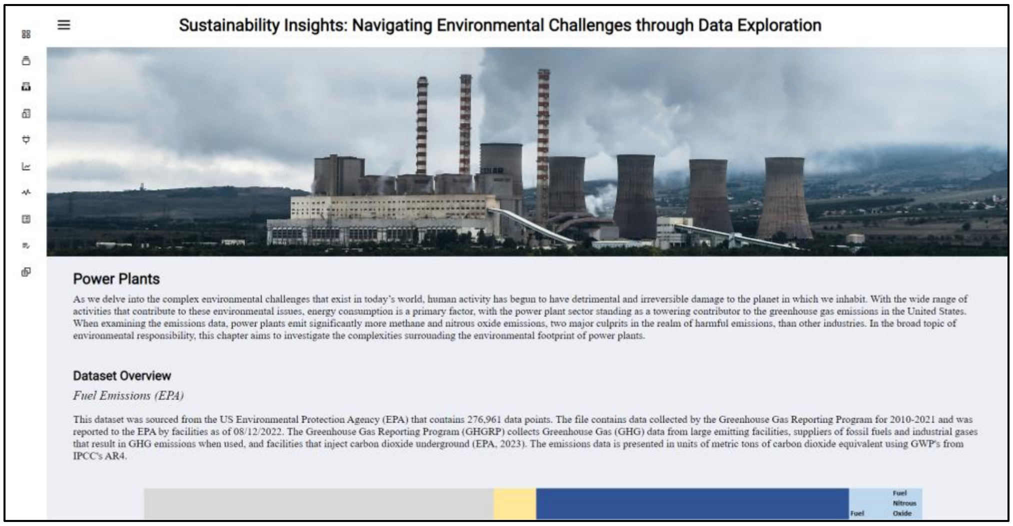

Figure 33: Screenshot of sustainability website

At WPI’s Undergraduate Project Presentation Day, where we showcased our project, many judges, who were WPI faculty members and graduate students, as well as our peers presenting alongside us, expressed their excitement and interest in our project and the sustainability initiatives at WPI. Most of these individuals shared that they were unaware of the ongoing sustainability efforts happening on WPI’s campus and expressed great interest and ideas about getting involved in the future. Their keen interest and eagerness about the universities initiatives emphasizes the importance of our project; effective communication and collaborative efforts are imperative to driving sustainable change within the WPI community.

Future Work

To build upon the groundwork laid by this project, future endeavors could focus on further developing the sustainability website as an educational resource for the community. Additionally, creating a WPI sustainability dashboard could serve as a vital tool for the Office of

Sustainability, enabling comprehensive tracking and analysis of initiatives. Moreover, the development of a public, interactive dashboard could enhance climate communication and encourage greater involvement in sustainability efforts across the campus community. By continuing to innovate and collaborate, WPI can reinforce its commitment to sustainability and serve as a beacon of environmental stewardship in higher education.

Acknowledgements

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Appendices

Appendix A: Datasets Used

Dataset #	Dataset Name	Date Accessed	Used For	Source
1	WPI Utility Usage	2/28/2024	Main dataset	WPI’s Office of Sustainability
2	WPI Greenhouse Gas Emissions Tighe & Bond Report	2/28/2024	Main dataset	WPI’s Office of Sustainability
3	UMA Greenhouse Gas Emissions	3/26/2024	Supplementary dataset	UMA’s Office of Sustainability
4	Emissions by Unit and Fuel Type	9/11/2023	Main dataset	U.S. EPA
5	Trends in Atmospheric Gas Concentrations	12/5/2023	Supplementary dataset	GML NOAA
6	Annual Surface Temperature Change	12/5/2023	Supplementary dataset	IMF (FAO)
7	Power Plants and Communities	12/5/2023	Supplementary dataset	U.S. EPA
8	Rates in Heart Disease and Stroke Mortality in US Adults	11/10/2023	Supplementary dataset	U.S. EPA, U.S. CDC
9	U.S. Chronic Disease Indicators (CDI)	11/03/2023	Supplementary dataset	U.S. CDC

Appendix B: Sustainability Website

The team has created a website to encompass the work done for this project as well as to demonstrate the effectiveness of a website in facilitating communication and information sharing regarding sustainability initiatives at WPI. The link for the website is: https://bhansea.github.io/SustainabilityMQP/