Waste Management

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Abstract— More than 12% of the world's waste is produced by the United States, with 62% of waste discarded by homes and companies being dumped in landfills or burned in incinerators. This project was undertaken to 1) understand the waste management process and four methods of waste management 2) analyze MSW and its important sector plastic by these four methods 3) visualize the impact on the environment. Streamlit based on Python is used in this project to create interactive visualizations, and linear regression is applied to predict carbon dioxide equivalent emissions from waste in 2022. With the hope of raising awareness of waste management and promoting a cleaner environment, this project ultimately constructed an interactive narrative website.

Index Terms—Waste Management, narrative, visualization

1 Introduction

Every year, the globe creates 2.01 billion tons of municipal solid garbage, with at least 33% of that not being managed in an environmentally sustainable manner. Worldwide, waste generated per person per day averages 0.74 kilograms but ranges widely, from 0.11 to 4.54 kilograms.

Despite having only 4% of the world's population, the United States produces more than 12% of the world's waste. In 2018, the United States wasted more than 292 million tons of municipal solid waste (MSW), which includes materials abandoned by residences, companies, and institutions such as universities and libraries. The majority of waste (62%) discarded by homes and companies in the United States is eventually dumped in landfills or burned in incinerators.

After seeing the amount of waste we produce, we are motivated to do a waste management project in order to reduce our impact on the environment and preserve natural resources. This project will not only help us to understand the waste management process and the four methods of waste management but also visualize the impact on the environment. We hope this project can make people a deeper understanding of waste generation, classification, and emission and then promote a cleaner and healthier environment.

2 Related Work

2.1 Waste Management

Waste Waste has been defined in most countries and is generally tied to the concept of disposal [2]. Given the definition of EPA [3], waste can be divided into hazardous waste and non-hazardous. Hazardous waste includes radioactive waste, industrial waste, electronic waste, and medical waste. Non-hazardous waste is also called solid waste, and the largest part of solid waste is municipal solid waste.

Municipal Solid Waste (MSW) is commonly called trash or garbage. This category generally refers to common household waste. as well as office and retail wastes but excludes industrial, hazardous, and construction wastes.

Waste Management Waste management is a significant global environmental concern. The increase in solid waste generation rates is the result of human activities and changes in lifestyles and consumption patterns. Waste management is also used to recover resources from waste [4]. Waste management involves the collection, transportation, processing, recycling, or disposal of waste materials. It also involves monitoring waste to ensure it is managed properly. A typical waste management system includes collection, transportation, pre-treatment, processing, and final disposal of waste. The goal of waste management is to provide sanitary living conditions and reduce the amount of waste that enters or leaves society. It also aims to encourage the reuse of materials within society [1].

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2.2 Greenhouse Gas Emission

As global warming becomes a more pressing environmental issue, many studies have focused on the topic of greenhouse gas (GHG) emissions from waste management activities. It is estimated that the postconsumer waste sector contributes 3-4% to total global anthropogenic GHG emissions, with a contribution of 49×10^9 tonnes CO_2e per year in 2004-2005. While this contribution may be considered relatively small, there are still untapped opportunities for reducing carbon emissions in the waste sector, particularly in developing countries [5].

MSW is a global concern. The way we manage MSW can impact the release of greenhouse gases, which contribute to climate change. According to the latest U.S. Environmental Protection Agency (EPA) inventory of GHG emissions, the waste management sector accounts for 4% of total U.S. anthropogenic GHG emissions. Landfills are the largest source of methane (CH4) in the United States and accounted for 90% of GHG emissions from the waste sector in 1999 [6]. Emissions of CH4 occur as biodegradable materials like paper, food scraps, and yard trimmings break down in the waste stream.

3 Methods

Streamlit is an open-source app framework in Python. It contains frameworks such as scikit-learn, spaCy, and Pandas, and also various visualization frameworks such as Altair, Plotly, Vega-Lite, and Matplotlib, which allow users to create interactive visualizations by using javascript, HTML, and CSS language within Python.

Streamlit was the main app used in the project. Streamlit functions were used to design the layout of the web page, which is mainly composed of a sidebar and main web pages, and to create the drop-down menu and the check box to view different plots by selection. A library like Altair was used to create linear, area, and pie charts with tooltips and zooming functions. Also, linear regression on the time series data was accomplished by Altair regression functions. Plotly was used to create a scatter plot on maps with a circle size to represent the number of emissions from waste in each location.

Linear regression algorithm is a machine learning algorithm used for supervised learning. This regression finds out the linear relationship between a dependent variable and the independent variables. Within this project, linear regression was used to predict a dependent variable, which was the CO2 equivalent emission from each sector of waste in 2022, from the independent variables, which was the year.

The web deployment was accomplished by pushing codes and data files to Github and then connecting the Github link to Streamlit.

4 Discussion

The audience should be able to answer the following questions ranging from the definition of waste, and different kinds of waste such as hazardous waste, non-hazardous waste, and municipal solid waste. Greenhouse gas emission trend from facilities of the sector of industries.

From the narrative visualization, plastic waste has grown from 8.2 percent in 1990 to 12.2 percent in 2012. With the alarming rate, we as a global community have to take action into our own hands. Without a doubt, the plastic waste percentage will continue as plastic usage is too far important and Incorporated into our daily life. During the COVID pandemic, we see a spike in plastic cups and plastic containers for takeout eating and a shift in dietary customs due to COVID. The remedy is to help kind slow down the process, better legislation, better product design, and better general public awareness of recycling practices and values.

By the map of the location of reporting facilities in the waste sector many large industrial waste landfills are in southeastern states and along the coastline of the Gulf of Mexico, which is also where numerous petroleum refineries, pulp and paper, and chemical manufacturing facilities are located. Where the mismanaged and uncollected waste often ends up in terrestrial or aquatic environments, Polluting the ocean and marine life creating solid waste "islands" in the middle of the ocean. Ingestion, suffocation, and entanglement of hundreds of marine species. Marine wildlife such as seabirds, whales, fish, and turtles mistake plastic waste for prey. Most then die of starvation as their stomachs become filled with plastic.

One new insight that enables our waste management is during the span of 2011 to 2021, we see a decrease in the percentage in MSW landfill of total emission of carbon dioxide. The regulation, legislation, and the general public have helped shape the outcome of the production. The road to clean emission plastic usage is not done; there is still a long road ahead where awareness of recycling and values are essential in education, practice, and future endeavors.

5 Results

5.1 MSW and Waste Management

A line chart was used to illustrate the overview trends in U.S. waste management from 1970 to 2018. The chart shows that landfilling of MSW is currently, and has been for some time, the most common waste management practice. However, a large portion of the materials in the waste stream is now being recovered for recycling and composting, which is becoming an increasingly popular trend throughout the country. These materials would have previously been disposed of in a landfill.

A stacked area chart was used to demonstrate the trends in waste management by the material over the years. The chart included data on generation to allow for a better understanding of the management of each material. For instance, comparing the amount of waste generated to the amount of waste landfilled reveals that the proportion of waste landfilled has decreased from 94 percent in 1960 to 50 percent in 2018. Additionally, combining the area chart with an interactive pie chart allows for the display of both the specific amounts and proportions of each material. For example, the total amount of MSW recycled was over 69 million tons, with paper and paperboard making up about 67 percent of that amount. Metals accounted for about 13 percent, while glass, plastic, and wood made up between 4 and 5 percent.

5.2 Plastic

Since plastic is one of the most common wastes in municipal solid waste and has a drastic impact on the environment, it was chosen as a waste example to illustrate the waste management situation and the potential impact of waste on the environment.

To address the drastic increase in plastic production over the years, a line plot with a tooltip showing the data of each point was produced to show the plastic production in the world over the years. Also, an area plot with a tooltip showing the cumulative production of plastic globally was plotted to emphasize further the huge amount of plastic waste around the world.

A stacked bar chart was used to represent the percentages of each waste management technique used in plastic waste treatment globally in 2019. Also, a stacked area plot was used to show detailed information about the change in the amount of plastic waste managed by different methods from 1960 to 2018. Those two plots illustrate the waste management method of plastic waste and embody that plastic waste was mainly managed by landfill, which is the least preferred method because it may take up to 500 years for plastics to decompose. Also, the plots aroused people's attention that only little amount of plastics are recycled, which is because the recycling of plastics can be contaminated by mixing plastics of different chemical compositions, and the importance of performing garbage classification correctly.

Building on the plastic waste treatment in 2019, we focused on OECD countries, where OECD stands for The Organization for Economic Co-operation and Development, where countries, including the United States, come together to seek solutions to common problems. OECD works with governments to understand how the economy is changing and to help them learn from each other so they can improve their policies back home. A stacked bar chart illustration of the World with OECD countries is created to visualize the economic trends and their contribution. Plastic waste is often managed by four different methods, recycled, mismanaged, incinerate and landfilled. From the stacked bar illustration, we see that 9 percent of plastic waste is recycled, while 22 percent is mismanaged. This is a huge problem where this problem requires action, and cooperation, including innovation, better product design, and environmental alternatives.

5.3 Greenhouse Gas Emission

Greenhouse gas emissions by facilities and emissions showed that waste generated through methane from anaerobic decay in landfills and nitro-us dioxide from solid waste combustion contribute generation of greenhouse gas trapping heat in the atmosphere. Enlarging the ozone layer depletion, aggregating global warming in general. People tend to focus on Power Plant emissions of GHG and Oil & gas industries and power generation for electricity from fossil fuels but tend to ignore the waste producing of Green House Gas. From the bar graph above, OECD produced 22 percent of mismanaged waste, whereas in OECD countries, including the United States. Visualization revealed by the emission sector and number of facilities that solid waste is ranked second in the number of facilities alone behind Power Plants. This is a significant insight; whereas the world transition to green energy like electric vehicles, wind energy, and solar energy, we also can envision reducing plastic waste. We need to actively take charge of mismanaged waste in greenhouse gas facilities by legislation and policy to take charge of plastic management.

Reducing greenhouse gas emissions from solid waste, plastic production, and combustion is a critical step in the fight against climate change. In recent years, there has been a growing awareness of the need to address these issues, and as a result, legislation and policy changes have been put in place to help reduce emissions in these areas.

One of the key ways to reduce greenhouse gas emissions from solid waste is through waste reduction and recycling programs. By reducing the amount of waste we produce, we can reduce the amount of waste that ends up in landfills, where it decomposes and releases methane, a potent greenhouse gas. Recycling programs can also help to reduce emissions by diverting waste from landfills and instead using it to create new products, which can help to reduce the need for new plastic production.

Another way to reduce greenhouse gas emissions from plastic production is by transitioning to more sustainable methods of plastic production. One example of this is the use of bioplastics, which are made from renewable resources such as cornstarch or sugarcane instead of fossil fuels. By using bioplastics, we can reduce the emissions associated with plastic production, as well as the amount of plastic waste that ends up in landfills.

In addition to these measures, policy changes can also play a role in reducing greenhouse gas emissions from combustion. For example, many governments have implemented policies to promote the use of renewable energy sources, such as solar and wind power, which can help to reduce the amount of greenhouse gas emissions from the burning of fossil fuels. In addition, some governments have also implemented regulations to limit the number of greenhouse gases that can be emitted from vehicles and other sources of combustion.

Overall, reducombustionnhouse gas emissions from solid waste, plastic production, and combustion is a crucial step in the fight against climate change. By implementing waste reduction and recycling pro-

grams, transitioning to sustainable methods of plastic production, and promoting the use of renewable energy sources, we can help to reduce emissions and protect the planet for future generations.

Our website featured a map that gave our audience a sense of the location of each emissions-reporting facility in the waste sector. The circles on the map corresponded to different ranges of emissions in metric tons of CO2e reported by each facility, with larger circles indicating higher levels of emissions. The map showed that many large industrial waste landfills are located in the southeastern states and along the coastline of the Gulf of Mexico, which is also where many petroleum refineries, pulp and paper mills, and chemical manufacturing facilities are located.

To predict the greenhouse gas emission by each waste sector in 2022, we performed linear regression on the time series data from 2011 to 2021. By using the drop-down menu, Users can explore the raw data shown by scatter and the linear regression line with R-squared values and regression equations of different waste sectors, including municipal solid waste landfills, solid waste combustion, industrial waste landfills, and industrial wastewater treatment. Although all sectors show a drastic decrease over the years and by 2021, the decrease in total emissions from waste sectors reached 10.1% percentage, the main reason for the decrease is due to the changes in the rule for calculating methane emissions from MSW landfills. Starring in reporting the year 2013, MSW landfills are allowed to assume that a higher percentage of methane generated by the landfill is oxidized to carbon dioxide as it passes through the landfill soil cover, resulting in lower reported methane emissions. The prediction of the greenhouse gas emission of each waste sector was calculated by the fitted linear model and summarized in the data frame, in which users can rank the number by their preference.

6 Future Work

In the future, since the R-squared values for some of the linear models are small, indicating a weak linear correlation between greenhouse gas emission and time, we plan to develop a sophisticated model for predicting greenhouse gas generated from different waste sectors. Those models will be more accurate and will take into account a wider range of factors, such as air temperature, humidity, and wind speed.

To make our website more user-friendly, we will use JavaScript to build our website from scratch and create more flexible and attractive visualization designs. The interface will be intuitive and easy to navigate, with a range of options for users to customize their experience.

In addition, we will create more interesting graphs and charts to help users interact with the data. These will be interactive and will allow users to explore different scenarios and see how different factors impact greenhouse gas emissions from waste management.

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