Reducing Methane Emissions Through Municipal Waste Management

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Introduction

Goal: Investigate the connection between methane emissions, municipal waste, and country population to predict future trends in methane emissions as the result of municipal waste.

Hypothesis: There will be a positive correlation between methane emissions, waste, and population in each country.

Methods

1. We began by collecting three datasets, one for each of our three variables: Population, Waste, and Emissions. The data was sourced from the World Bank, the United Nations, and Climate Watch respectively.
2. We picked the top five countries by population that were contained in all our datasets, and then divided up the countries between team members.
3. Each team member preformed research on the correlation of the three variables within their assigned country and created time-series visualizations for each of these variables.
4. We complied our findings to produce predictions and prescriptions for methane emissions in each of our countries.

Overall Trends

Population: Population is the amount of people in the country.

- Trend: Population is generally positively correlated with waste, but not always with emissions.

Waste: Waste is the amount of Municipal Solid Waste (MSW) collected in a country and stored in landfills, measured in 1000's of tonnes.

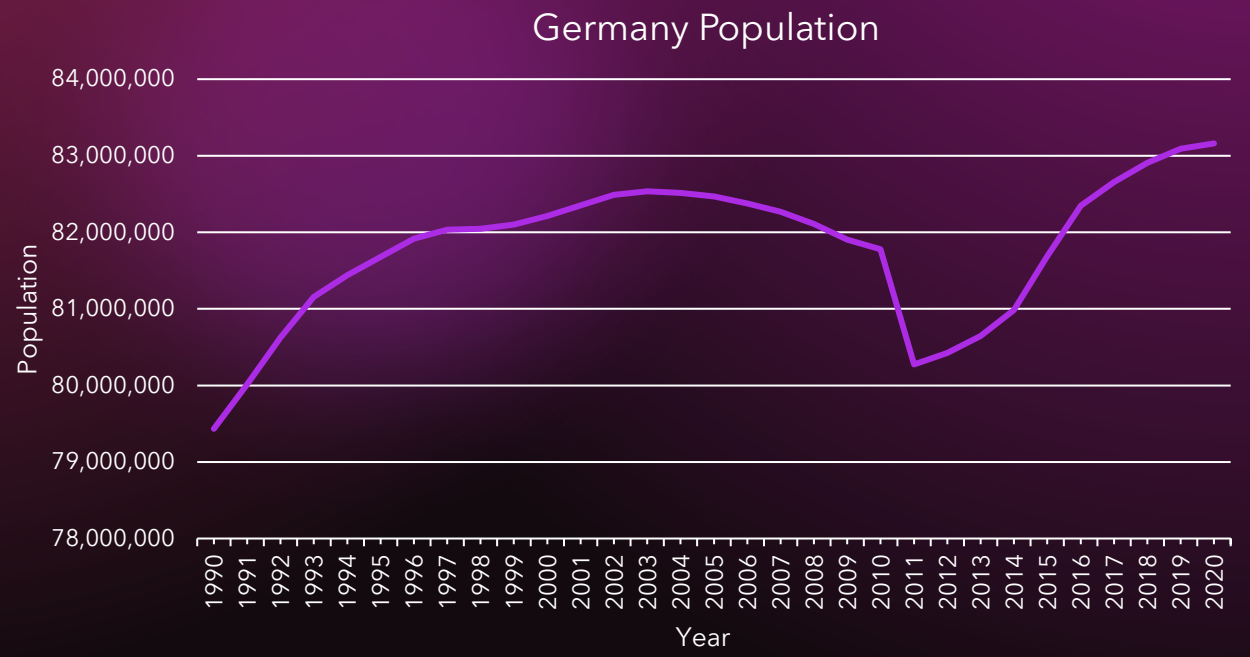
- Trend: It varies by country, but overall, waste has a generally positive correlation to population, and little correlation with emissions. This observation goes against our hypothesis, as we would expect more waste to result in more methane emissions.

Emissions: Emissions is the amount of methane produced in a country, measured in metric tons (tonne) of carbon dioxide equivalent ($MtCO_2e$)

- Trend: Overall, methane emissions share little correlation with waste, and a sometimes negative correlation with population, depending on the country. This observation runs contrary to our hypothesis, as well.

Germany Population

- Trend line is unsteady
- Drop of 1.5 million people around 2011/2012
- Anomaly comes from census calculations
- One of the “fastest aging countries” due to longer life expectancies and falling birthrates



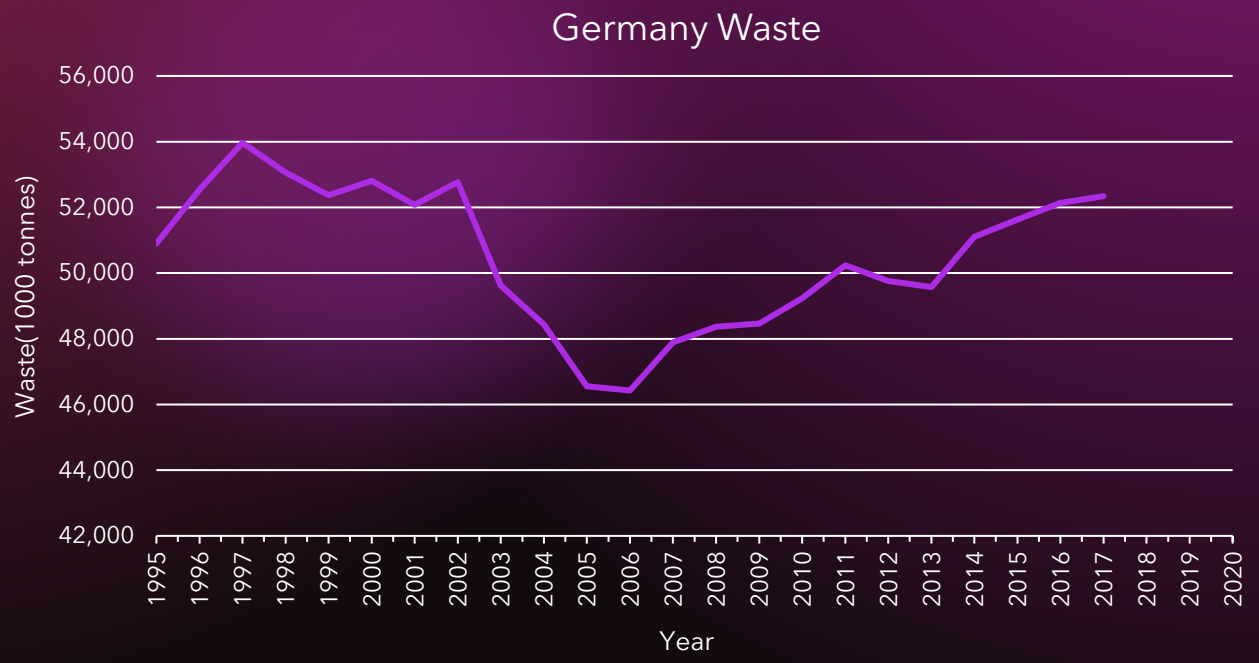
Germany Waste

Possible Reasons for Decrease in Early 2000s

- Germany increased their recycling rate from 48% in 2001 to 62% in 2010
  - Mandated by EU's 2020 recycling target
- Recycled MSW not tallied in data

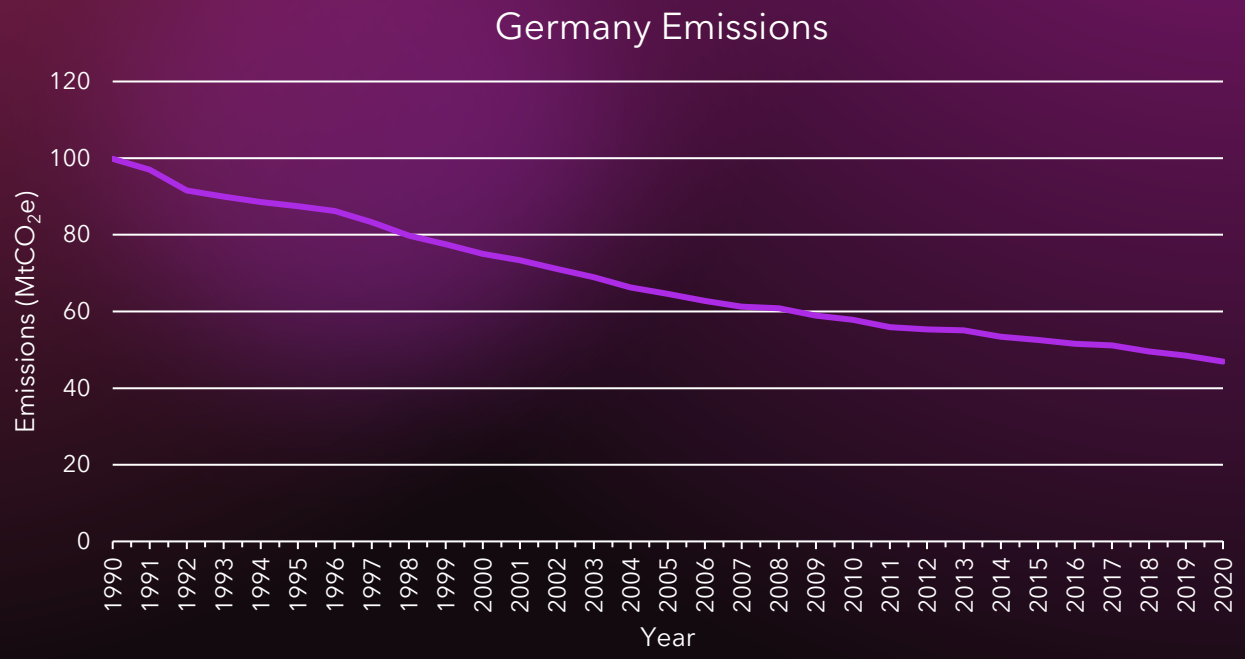
Possible Reasons for Increase in Waste after 2006

- Many possible reasons for increase in waste
- Total waste is dominated by building waste (54%) which is reflected by the increase in the German Construction Industry
- Also, huge increase in packaging waste post Covid-19



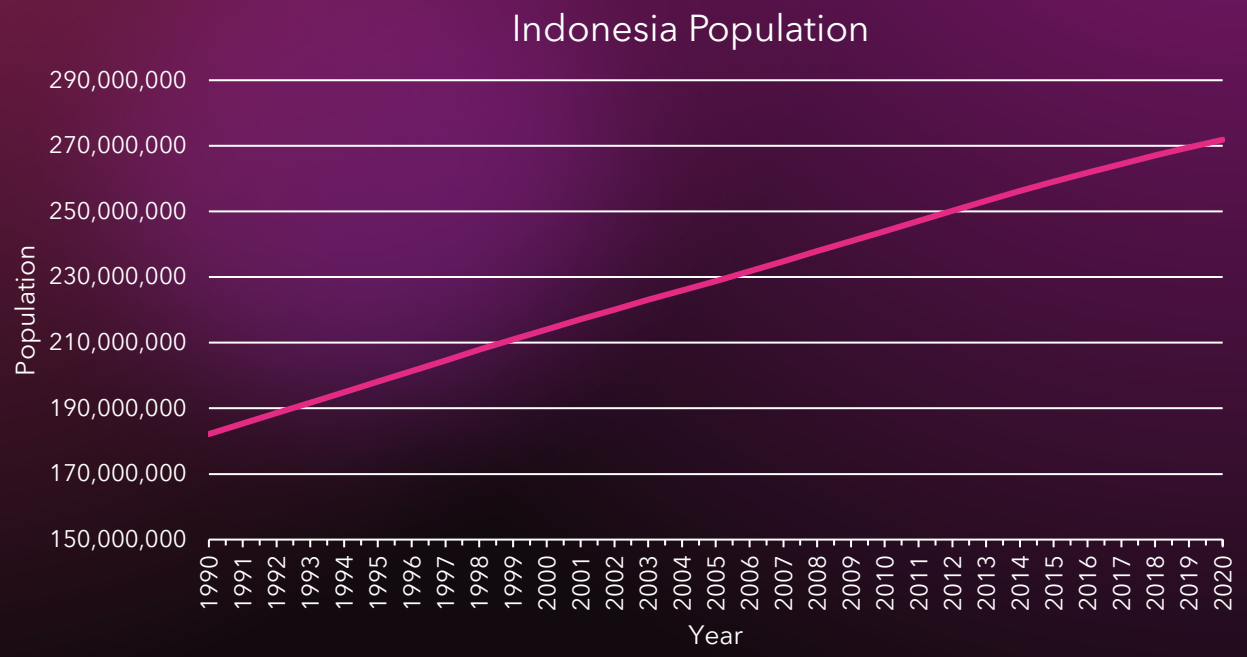
Germany Emissions

- EU's greenhouse gas emission reduction plans
- National law plans to cut greenhouse gas pollution 65% from 1990 to the end of the decade (2030)
- 53% decrease in methane emissions as of 2020
- Has a negative correlation with population



Indonesia Population

- The population uniformly increases at a nearly linear rate from 1990 – 2020.
- No strange outliers or unexpected trends



Indonesia Waste

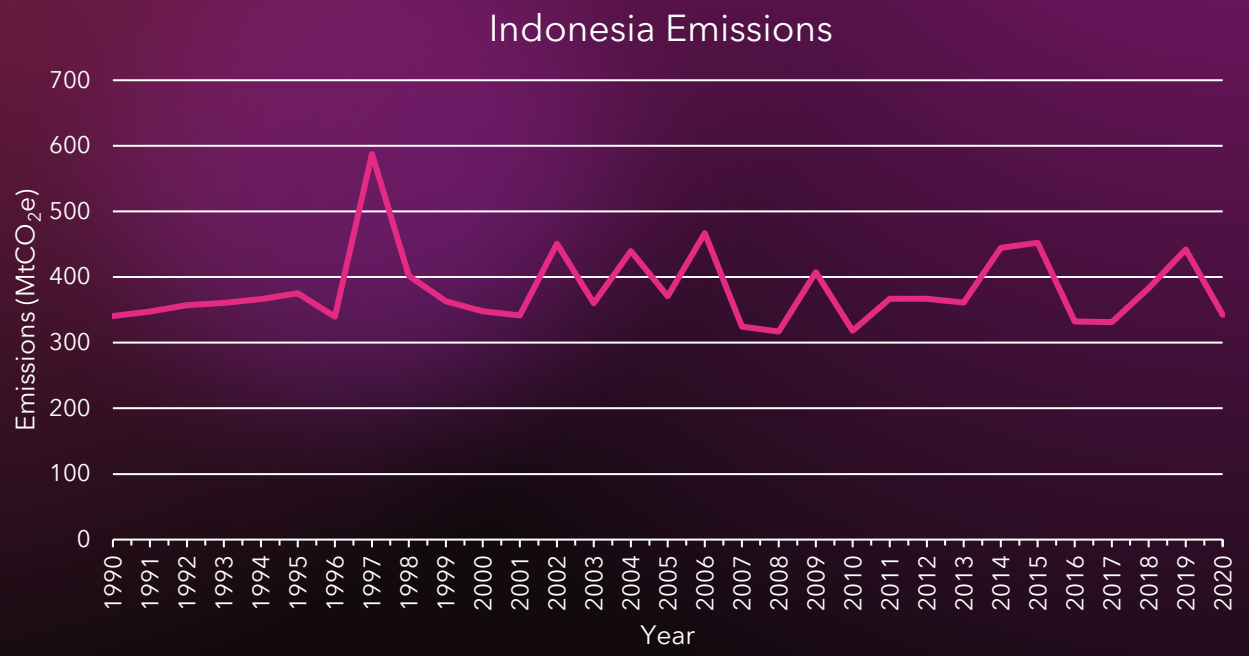
- Waste data increased overall during the 30-year span, but did not increase uniformly
- Indonesian waste production, contrary to its greenhouse emissions, is extremely small, especially when considering its large overall population.
    - Opposite of what we predicted: could be due to under-reporting, especially when considering the amount of missing data values

Actual

Edited

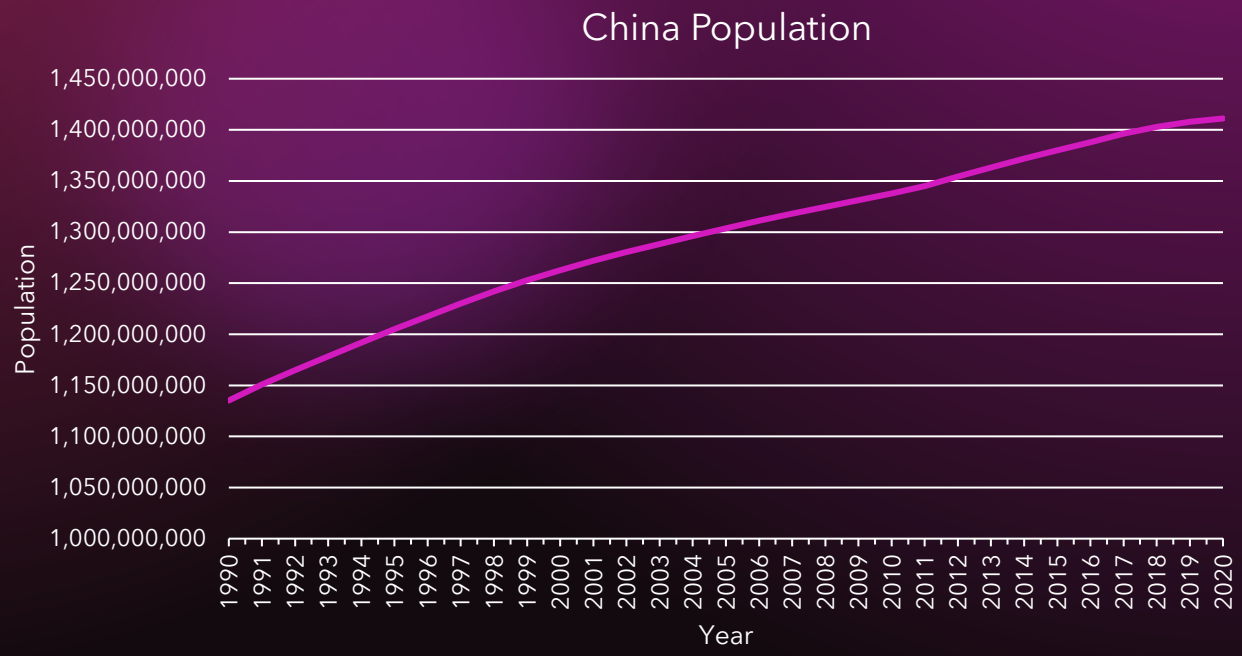
Indonesia Emissions

- Emissions hovered near the same values over the course of our investigated years
- Extremity in 1997 due to devastating Indonesia forest fires
    - Resulted in highly elevated methane levels in the atmosphere
- As population and waste increased, Indonesia's emissions did not experience a similar phase of growth.
- Most annual Indonesian emissions are due to land-use/forestry



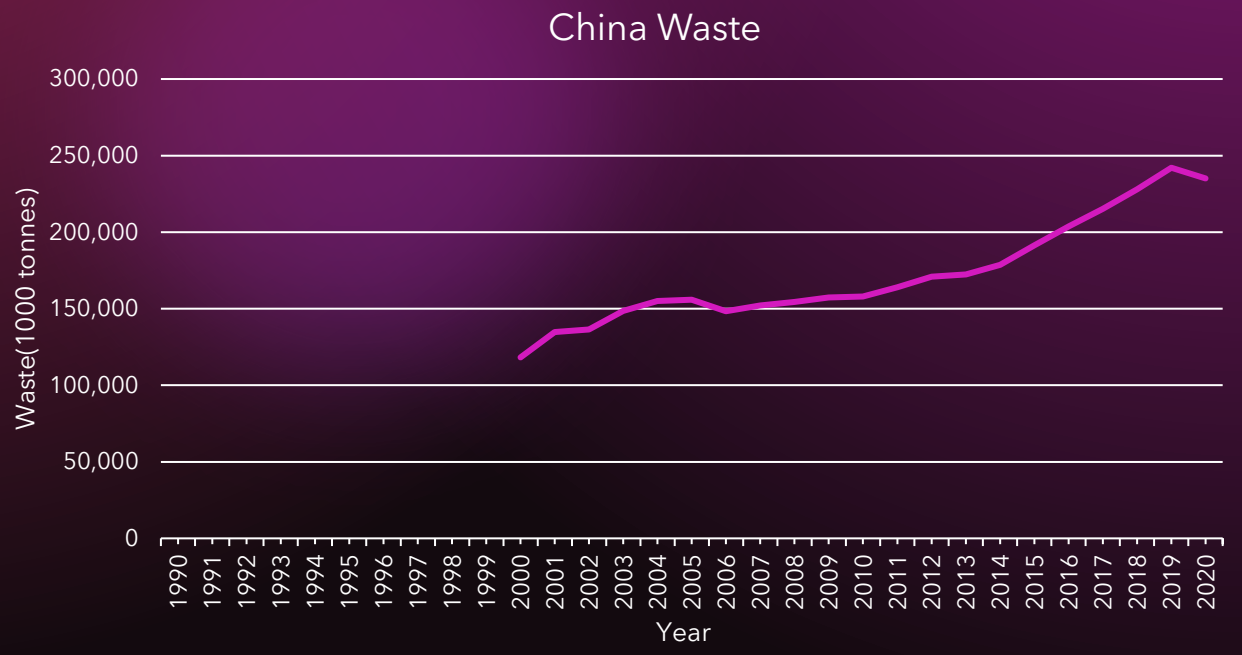
China Population

- Positive linear growth of population over time.



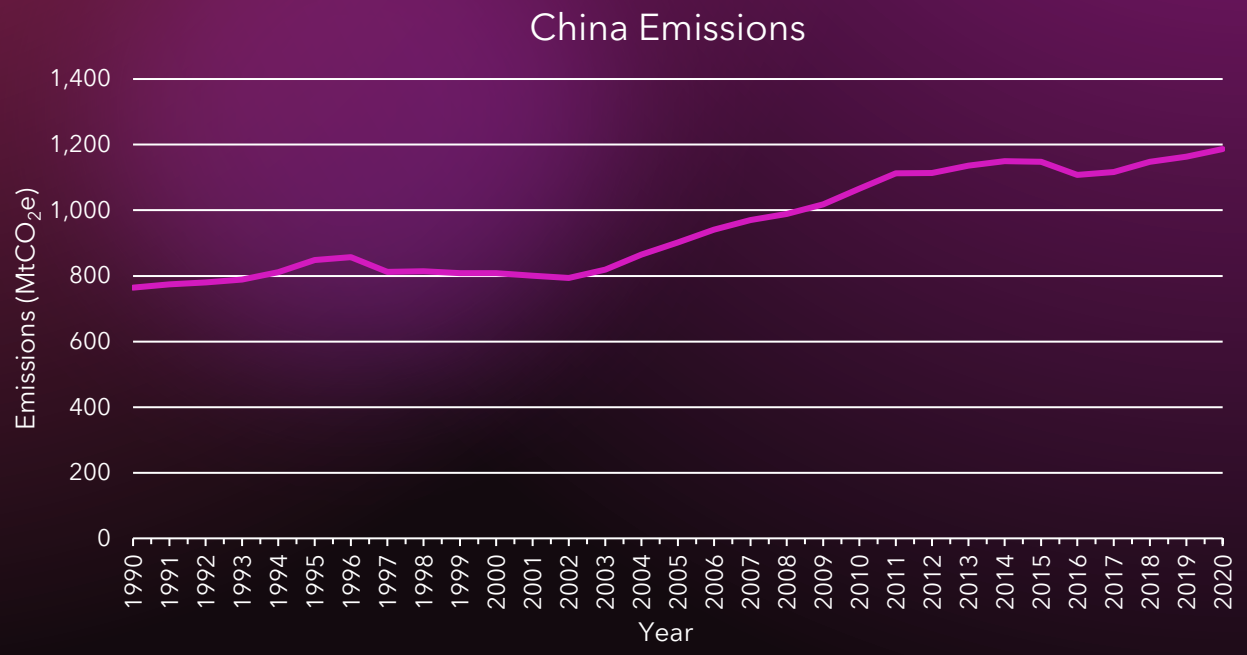
China Waste

- Relative maximum in 2005, followed by a decrease.
- Decrease due to China's efforts to reduce its waste beginning in 2004 with improved landfill management and an increased budget for municipal waste management.
  - Efforts had an impact, but the increase resumed in 2006 and continued until 2019.
- 2019 decrease due to China's compulsory waste sorting law, which eased burden on landfills.



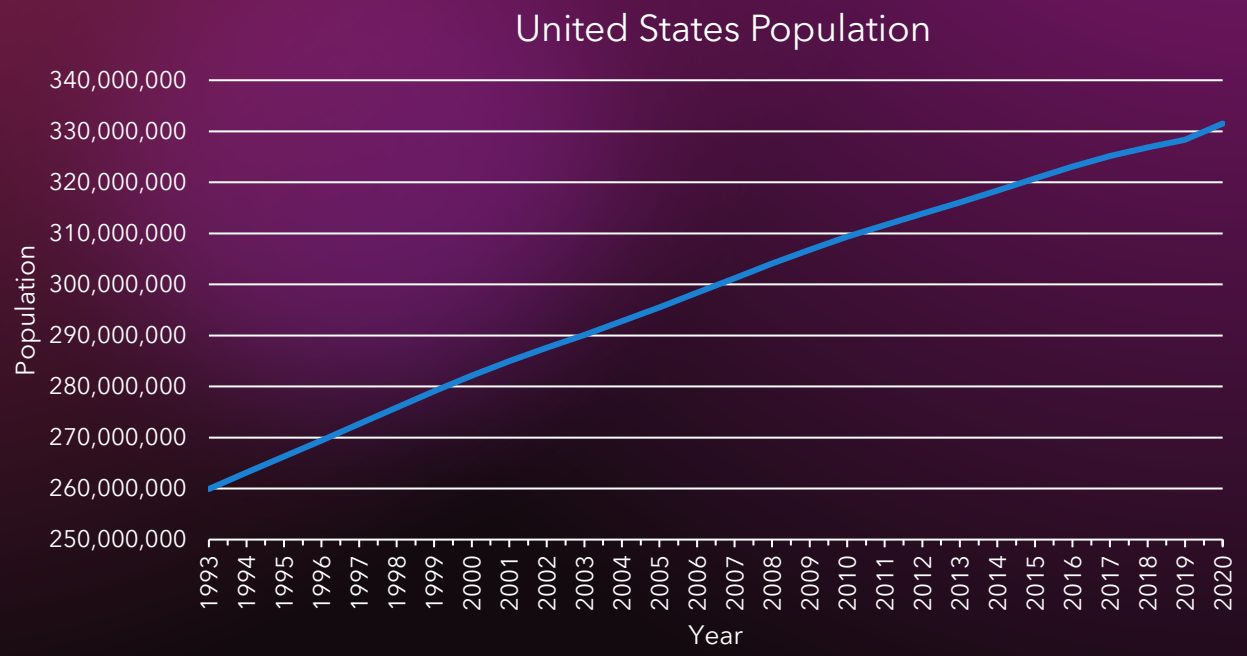
China Emissions

- Increasing emissions from 1990 to 2020.
- "Coal mining, rice cultivation, ruminant livestock, and waste management are thought to account for about 90% of the country's total methane emissions." (Sheng et al., 2021)
  - As previous graph demonstrates, waste is rising, so it makes sense that emissions would be rising also.
- There are also other factors influencing China's methane emissions, but waste and population are significant contributors, as demonstrated by the positive correlation between these variables for most years.



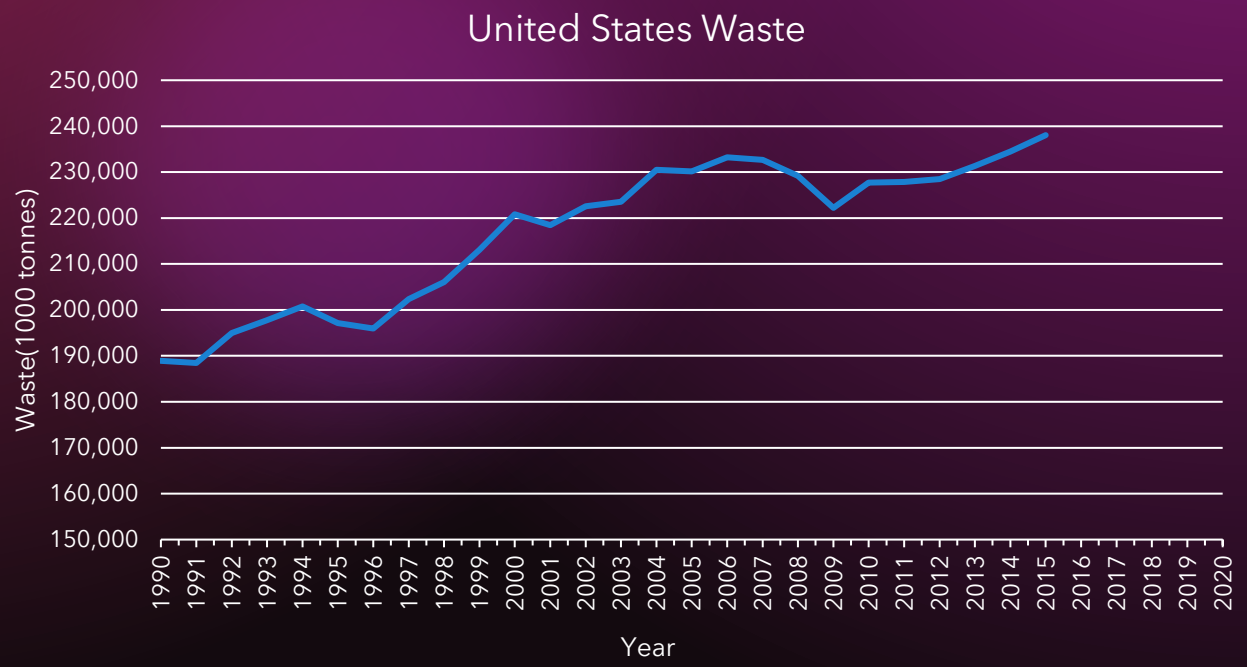
United States Population

- Population in the United States is increasing linearly.



United States Waste

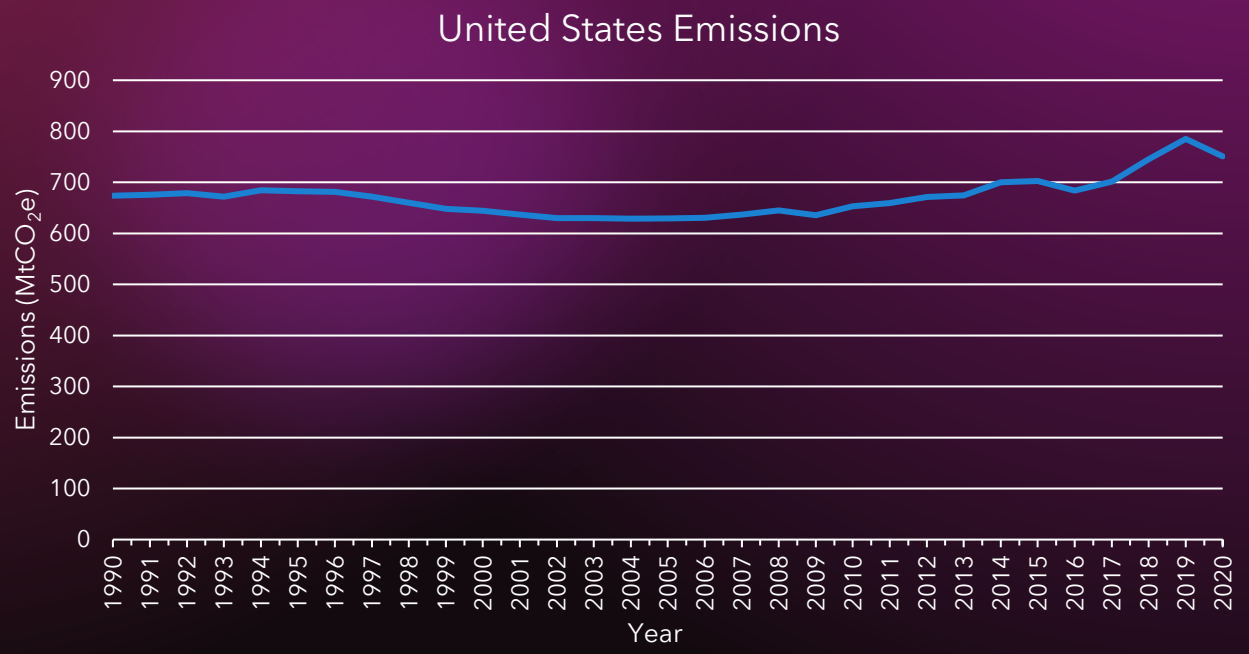
- There is a trend of increase in waste from 1990 to 2016.
- As population increases, there are going to be more people producing waste, in turn, there is expected to be an increase in waste every year, which the graph reflects somewhat accurately.
- Many policies have been put into place to limit the amount of waste generation, but the growth of the US population has mostly outpaced the effects of these policies.



United States Emissions

- During the Clinton administration (1993-2001), there were a lot of policies and standards put into play to lower emissions, reflected by the decrease over that time period in the graph.
  - Enforced tough standards on soot and smog

- During the Bush administration (2001-2009), a more passive route to emission reduction was taken, resulting in the gradual increase in emissions following Bush's tenure.
  - Bush had more relaxed environmental regulations.



Predictions

Germany: Greenhouse gas reduction plans put into national law will most likely result in a 12% decrease in emissions by 2030. After 2030, we predict that emissions will stay steady

Indonesia: The amount of waste should continue to increase due to the strong positive correlation with population; however, the emissions are expected to remain around roughly the same value due to no exact trend in the population/emissions data.

China: The positive correlation between population, waste, and methane emissions in China indicate that as China's population and waste production increase, methane emissions are likely to continue their increase.

United States: Since the population is still expected to grow, we would expect waste to continue to increase. With the lowering concerns of emissions with today's current policies and increasing waste levels, we would expect emissions to continue to increase as time goes on.

Prescriptions

Germany: Germany should continue with their greenhouse gas reduction plans as they have already decreased over 50% in the past three decades. Germany's waste production on the other hand has begun to increase, revisiting their strategy in the 2000s centered around recycling could begin to reduce their waste again.

Indonesia: Indonesia should continue with the changes brought by Law No 41 of 1999 and Law No 32 of 2009, which aim to increase the resilience of Indonesia's forests to fires. This will assist in lowering Indonesia's methane emissions by preventing future methane-releasing fires.

China: China has already made strides towards reducing the amount of municipal waste being directed towards landfills with required trash sorting. We believe additionally legislation enforcing this sorting will help to decrease methane emissions by reducing the amount of waste decomposing in landfills.

United States: One big stride the United States is making is the increase in more renewable energy sources and more effective use of energy. Programs like Energy Star and other federal and state initiatives have helped continue to lower the amount emissions produced, thus they should be continued.

Conclusion

Conclusion: Methane emissions are sometimes influenced by waste and population, but more often, there exist extraneous variables that play a larger role in methane emissions than waste does. Methane emissions can be controlled through the regulation of those extraneous variables, as we defined in our prescriptions. Overall, methane is rarely correlated with just waste levels, and is more often influenced by not only waste but also government intervention, methane producing activities, and natural events.

Reflections : We felt that our team worked efficiently together and performed quality data exploration over the course of this project. As a team, we also had to work through the challenge of sorting through incomplete datasets and discovering our hypothesis was mostly incorrect. Given the opportunity to redo the project, we would dedicate more time to considering the effect of extraneous variables on methane emissions, as this was a consistent influencer of our results.

References

Population Data: https://data.worldbank.org/indicator/SP.POP.TOTL

Waste Data: https://data.un.org/Data.aspx?d=ENV&f=variableID%3a1814

Emissions Data: https://www.climatewatchdata.org/ghg-emissions?end_year=2020&gases=ch4&sectors=waste&start_year=1990

Research Used in Slides:

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- Forest Legality Initiative. https://forestlegality.org/risk-tool/country/indonesia

- Sustained methane emissions from China after 2012 despite declining coal production and rice-cultivated area. https://doi.org/10.1088/1748-9326/ac24d1

- The Clinton Presidency: Protecting Our Environment and Public Health. https://clintonwhitehouse5.archives.gov/WH/Accomplishments/eightyears-08.html#:~:text=The%20Clinton%20Administration%20accelerated%20the