# Sustainability & Waste Management in Singapore

Dalia Zizumbo - zizumbo.d@northeastern.edu

Vidushi Misra - misra.vi@northeastern.edu

## Problem Statement and Background

A current problem affecting many people in Singapore is sustainability and waste management. Singapore is a small country with an area of 283 miles sq, and only has one landfill for all waste. The Semakau Landfill, in Singapore is suspected to run out of space by 2035 and has many residents worried. Since Singapore has limited space it is very difficult dedicating additional land to incineration plants or waste. A way the government is trying to fix this on going issue is by taking steps to becoming a zero waste nation. The government is pushing its residents to recycle in order to reduce the amount of waste produced each year, given that the was being disposed by residents keeps increasing every year.

We used gathered data from The National Environment Agency of Singapore annual waste management data at https://www.nea.gov.sg. The format of this data is in a table csv where the top row is separated by year, waste type, total generated, total recycled, the recycling rate, and the total disposed. In the data there are a total of fourteen different types of waste. Along-side under “Waste Type” is a column of fourteen different waste types. We also gathered more information from Green Tumble’s data about energy saved through recycling at https://greentumble.com for every type of product recycled. The format of this data is in a table csv where the top row is separated by materials recycled per one ton, energy saved in kWh, oil saved in barrels, omitted air pollutants in pounds, water saved in gallons, landfill space not used in cubic yards, and other resources saved. Followed by four different types of recyclable material being paper, plastic, glass, and aluminum.

**Introduction and Description of the Data**

Having grown up in Singapore, one of the world's most sustainable cities, Vidushi observed how there were consistently ongoing projects to reduce environmental impact. They implemented a variety of things like carbon tax, emissions trading scheme, energy efficiency standards for infrastructure and vehicles, green buildings, and lastly, investing in renewable energy. Being located in a tropical climate region, Singapore developed green spaces that span almost half the city while incorporating environmentally friendly infrastructure that reduces the urban heat island effect. Given their small land area, an alarming rate of waste generation meant that Singapore had to develop an effective scheme for recycling waste. Since we were both passionate about overconsumption and sustainable waste management, we realized analyzing Singapore's waste data would give us a good insight into waste management in an urban and environmentally conscious city.

After gathering information we had several goals in mind for our program. The problem of over consumption stems from citizens not knowing how recycling works and the impact it can have on things like energy. When citizens are educated on how recycling common household waste materials like paper, metals, glass, and plastic saves energy, fuel, labor, cost and time, they are more prone to taking action. Therefore, in our program, we wanted to visualize things like the proportion of waste generated and recycled, the recycling rates for common household-produced waste categories over a wide span of years, and the energy saved from recycling them. These visualizations would help us analyze the severity of overconsumption, the correlation of "recyclable" and "eco-friendly" materials, and lastly the impact recycling has on energy conservation. To visualize the above, we downloaded and modified a kaggle dataset that collected data from:

- The National Environment Agency of Singapore's annual waste management data at https://www.nea.gov.sg/our-services/waste-management. This website gave us access to Singapore's waste and recycling database dating from 2017 to 2022.
- Green Tumble's data about energy saved through recycling at https://greentumble.com/how-does-recycling-save-energy. This website allowed us to gain more information about the amount of energy saved from recycling for each category of waste.

We merged these two datasets because they went hand in hand with each other and made it simpler to see how much is being recycled and how much energy is being saved for common waste categories. There wasn't data available for energy saved for all waste categories, so we focused on plastics, paper/cardboard, glass, ferrous and non-ferrous metals, that are common waste categories generated.

The problem in Singapore associated with sustainability and waste management is important to talk about because many people around the world, like Singapore also struggle with an excessive amount of waste production. This issue stems from citizens not knowing how recycling works and the positive effects it can have on the community and planer. When citizens are educated on how recycling paper, metals, glass, and plastic saves energy, fuel, labor, cost and time they are more prone to making this change. Especially when sharing data comparing the amount of energy used to dispose of products in landfills and manufacturing new items there is a big difference in energy used when compared to reusing items already made. People in Singapore care about this issue because its affecting their quality of life through having waste trying to take up more of their land than they have set aside specifically for waste. This problem will have an impact on Singapore by causing waste overflow into their country and other regions in Asia, which will impact other citizens living around Singapore.  This issue can be made better by educating citizens on sustainability and waste management, and providing more recycling bins in neighborhoods, stores, and parks. By taking these steps one can ensure that citizens will start to recycle their disposables and have an understanding on how its helping their community decrease waste production and transforming it into energy.

**Methods**

The first visualization we produced depicted the proportion of waste generated and recycled for each category in the most recent year (2016) from our data. In order to depict this, we used a grouped bar graph wherein there were 2 bars for each waste category: one for waste generated and the other for waste recycled. Instead of making two separate visualizations to depict waste generated and recycled, we combined it into one so that the viewer could observe the proportion of generated waste that was being recycled. The purpose of this graph was to analyze how effective the current recycling processes are in recycling different materials, and for what materials, recycling processes can be improved. Being able to see the amount of waste generated from each category, would also help build awareness amongst people about overconsumption, and the excess waste being produced and disposed into the landfill.

The second visualization we produced depicted the recycling rates for common household-produced waste categories over a wide span of years. To achieve this, we created mini-dictionaries for the waste categories we wanted to plot the graph for. These mini-dictionaries would collect values for data points like the waste type, recycling rate, and year, so that the plotted points would be taking into account these 3 sets of information. We differentiated each waste category's plot by different colors and labels. This graph could give us insights into what materials are the most recyclable, and help us understand if there is a correlation between materials that are “recyclable” (having a high recycling rate) and “eco-friendly”. For instance, if plastic was shown to have the highest recycling rate, we would know that this correlation is negative because it is definitely not an eco-friendly material.

Our third visualization depicted the energy saved by recycling all the waste from categories like Plastics, Metals, Glass and Paper/Cardboard. To get this graph, we first had to merge the two datasets: the first containing data with respect to waste in Singapore, and the second being the one that included the amount of energy saved by recycling one ton of a waste category. There wasn’t data available for energy saved for all waste categories, so we focused on plastics, paper/cardboard, glass, ferrous and non-ferrous metals, that are common waste categories generated.

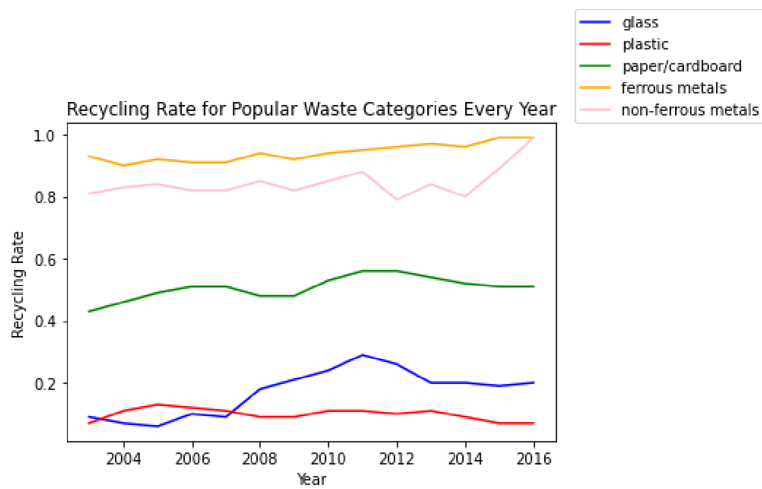
While creating the graph, we used a similar “dictionary” approach to the second visualization, except that instead of creating multiple dictionaries for each waste type, we created only one. We split the code for this visualization into two functions: one that made a dictionary to store values for waste type, calculated energy and year, and the other that actually plotted the graph. In the first function, in order to calculate the total energy saved by the amount of waste recycled in Singapore, we had to perform a calculation to multiply energy saved by recycling 1 ton to the total amount of waste recycled for each waste category.

While writing the code for the second function i.e. to plot this graph, I applied NumPy in order to create equal intervals for the years on the x axis. The main function consisted of the list of waste categories (and their dictionaries) I wanted to plot for, so that instead of plotting each waste separately like the second graph, I could plot all the waste categories at once.

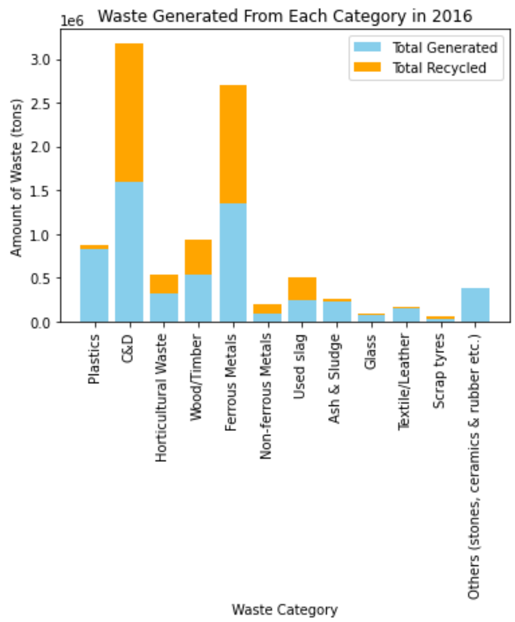
The end result of this visualization was a grouped bar graph that displayed the energy saved (on the y axis) by each waste category over the years 2003-2016 (x-axis). This graph visualized the impact recycling those materials have on energy conservation. Our hope would be that the data would motivate people to recycle their waste, given the potential amount of energy we can save from recycling. The program ended with our main function, where we called all our functions to implement each function, and plot each visualization.

**Results, Conclusion, and Future Work**

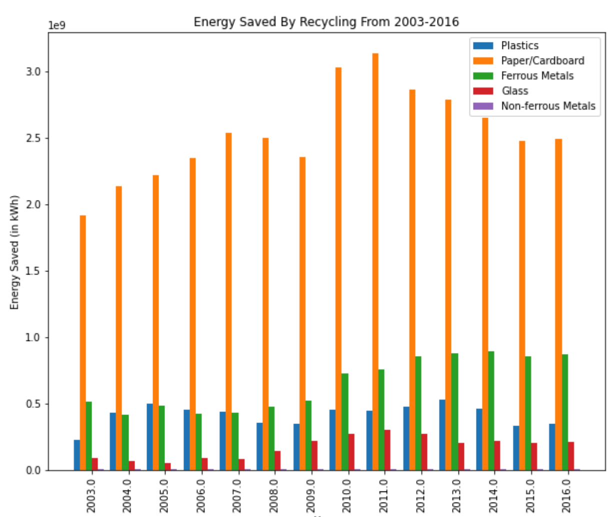
After researching sustainability and waste management in Singapore, we incorporated these datasets into our code and produced three different graphs. The first visualization produced shows the recycling rate for popular waste categories; glass, plastic, paper/cardboard, ferrous metals, and non-ferrous metals from 2004 through 2016.




We observe that the waste generated in even a small city like Singapore (population of 5 million), amounts to a number in millions with waste categories like construction and demolition, ferrous metals, and paper/cardboard producing the highest amounts. While a good portion of the waste is being recycled, the waste generated by paper/cardboard is still more than what is being recycled. The second visualization produced shows the amount of waste generated from each type of disposable in 2016, followed by the total amount recycled for each disposable.




We observed metals, paper/cardboard have higher recycling rates than glass and plastic. This proves that the correlation between “eco friendly” and “recyclable” materials are relatively positive because metals are materials that can be used over long periods of time, and don't have to be easily disposed. Paper and cardboard are also considered eco friendly because they are able to biodegrade easily. So, we could come to a conclusion that materials with higher recycling rates do tend to be more eco-friendly. Third and final visualization shows how much energy Singapore saved over 13 years from recycling.



After analyzing we noticed that paper/cardboard have a significantly higher impact when it comes to the energy conserved from recycling. This signifies how important it is for us to recycle. Also the negligible visualization for non-ferrous metals shows that even though it has a high recycling rate, is probably because of the negligible waste collected from that category. Through these three visualizations we learned about how prevalent the overconsumption issue is, even in a green city like Singapore, and analyzed the impact recycling can have in conserving energy.

After analyzing the data about waste management we had many strengths and shortcomings in our project. One of our strengths was showing three different categories; recycling rates, waste generated and recycled, and energy saved over the years. One of our shortcomings was that we did not merge more recent data from the years 2017-2020, which we could have collected and implemented code on if we had more time. In addition, we could have possibly made an interactive feature into the program with the other data we had about energy saved from recycling common household items like glass bottles, or stacks of newspapers, which was data we collected and merged into our csv file, but did not implement any function on. In the future we hope to continue researching this topic and think of better ways to analyze the data gathered through different visualizations once we have more experience with python.

**Citations**

Greentumble. (2018, September 10). How Does Recycling Save Energy? | Greentumble. Retrieved from Green Tumble website: https://greentumble.com/how-does-recycling-save-energy

National Environment Agency. (2022). Waste Statistics and Overall Recycling. Retrieved from Nea.gov.sg website: https://www.nea.gov.sg/our-services/waste-management/waste-statistics