Food Waste in the US:
The situation, causes, and effectiveness of government policy.

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1.   INTRODUCTION

The population on earth has been increasing. Currently, over 8 billion people live on the planet. Nonetheless, the United Nations indicates that over a billion people are suffering from starvation, and over 800 million people live in hunger for their whole life. To elaborate, one in nine people is starving for their entire life [14]. However, is the food the real world produces insufficient to feed 8 billion people?

Most organizations and governments have calculated and confirmed that the food the world makes right now is enough to let everyone in the world live without starvation. Still, because of food waste, hunger remains a critical issue worldwide. According to the Food and Agriculture Organization of the United Nations [9], one-third of the food is wasted. More specifically, 1.3 billion tons of food are wasted by spoiled, overproduced landfill and become forage for other animals. It is incredibly sarcastic that 1 billion are suffering from hunger, but wealthy countries produce surplus grinds intentionally to feed animals or use them as fuel. Among all the nations, the United States is the most notorious country for food waste.

According to ReFED (a national nonprofit dedicated to ending food loss and waste across the US food system by advancing data-driven solutions.), over 35% of food in the US is not sold or eaten [1]. If we convert the food waste into dollars, there are at least 408 billion dollars worth of food waste every year, and it is worth 2% of the GDP of the American economy. Hence, the US government did implement some policies to reduce food waste in 2015.

2.   MOTIVATION

Our motivation comes from our dining experience in the cafeteria of UW-Madison. When we have meals there, we always see students throw a lot of food away. The conveyor that transfers used dishes, bowls, and dinnerware is often full of unfinished food. Some of the food is not even bitten and only missing a corner. Moreover, we often see news reports about Africa's growing population and famine.

Figure 1: Maslow's hierarchy of needs [7].

Based on Maslow's hierarchy of needs, humans need to satisfy the conditions from the base to pursue the next level of needs. The first need people need to fulfill is Physiological needs, which include the essential things humans need in their daily lives. Of course, food is one of the principal elements, but nearly 15% of humans on the earth cannot meet this requirement. Thus, we want to dig more to realize the cause and effect of the food crisis on the world.

By analyzing the dataset that contains ten years of food waste data in states sorted by ingredient, food category, types of waste, and the value they are worth, we would like to focus on two main topics. First, which sectors waste the most food in the USA, and what food has been demolished the most? Secondly, the government of the United States carries out some policies to reduce food waste in the country. We want to analyze these food waste data and compare the food waste before 2015 and after 2015 to understand if policies are feasible or if the US government is squandering citizens' taxes on useless policies.

3.   LITERATURE REVIEW

Food waste is one of the most severe problems in the world. Jessica et al. (2015) [17] defined food waste as "... any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed of (including composted, crops plowed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)". Gustavsson et al. (2011) and Lipinski et al. (2013) stated that an average of 1.3 billion tons of global food is lost yearly from production to consumption [3]. The record levels of food waste have already caused negative results in food security, land use, and even climate change [16].

After looking at the global food waste problem, we could now narrow the scope to the United States. Since 1974, the US has had a significant increase in the food supply. During the thirty years of 1974-2004, as the population of the US increased, the supply also increased. Therefore, some may think that people have ingested the increased supply. However, as the Food and Agriculture Organization of the United Nations (FAO) investigated, food waste also increased yearly [12]. The US Department of Agriculture (USDA) estimated that food waste is about 30-40 percent of the food supply. This statistic is similar to the portion of global food waste, too. Wasting food not only costs environmental problems,

but the US government also needed to spend approximately 133 billion pounds and $161 billion worth of food in 2010 to deal with the food waste. Even when it went to 2013, the food produced for consumption was still wasted by 31% [15].

Fortunately, food waste has received growing attention from local and international. Governments of the residents have started to put more emphasis on it, and growing NGOs have been looking into the problem. Increasing concerns about food waste and its environmental impacts, such as greenhouse gas emissions and water footage, have also brought attention to the topic [5]. Many states in the US have developed pilot methods to catch up with the policy. For example, Madison and Fitchburg in Wisconsin launched a series of policies to reduce food waste. Starting in 2011, they put an alternative food waste box outside the street to separate it from the trash to reduce the amount of junk and turn the food waste into other organic manure [18].

Eventually, on September 16, 2015, the US Department of Agriculture (USDA) and EPA announced the US 2030 Food Loss and Waste Reduction goal, which seeks to reduce food loss and waste by 50 percent by 2030. This policy is the first-ever domestic goal to cut food loss and debris in the US [13]. This project is split into two measurements to measure the goal. The first measurement is the reduction of surplus. They set 2010 as a baseline for which a person caused 218.9 pounds of food waste per year. The goal is to reduce 50 percent of food waste that goes to landfill, which will approximately equal 109.4 pounds per person in 2030. The second goal is to reduce the supply amount of food. Again they took 2010 as the baseline. In 2010 food loss and waste at the consumption and retail level was 31 percent of the food supply. This project also encouraged companies to become the "Food Loss and Waste 2030 Champions" to help reduce food waste in their organizations.

Now that it has already been 2022, we would like to see whether the situation turns out well after the

policy has been released. We will focus on the data before and after 2015 to determine whether the approach works.

4. RESEARCH QUESTIONS

4.1. Which sector wastes the most food? Moreover, what is the most food waste in that sector?

In order to improve the food waste issue in the US, we hypothesize that a critical point that needs to be addressed is reducing the wasted top-ranked crops and ingredients. Since certain crops and food are wasted or overproduced often, organizations should focus on and develop solutions to adjust them.

Moreover, suppose we can analyze the dataset and know what sectors in the US tend to waste more food than other industries. In that case, the government can concentrate on those sectors more and legislate laws to limit them or assign related agencies to help them improve waste management.

As the article in USDA mentioned, the best way to reduce food waste is not to produce them in the first place [13]. Hence, we believe the information on what kind of food is wasted the most and what sector wastes the most can help reduce food waste.

4.2. After the US government implemented the food-waste policy in 2015, what were the changes before and after the release?

In 2015 the United States Department of Agriculture joined the US Environmental Protection Agency and set the goal to reduce food waste. The goal is to reduce 50% of the nation's food waste by 2030 [13]. To be more specific, these policies (EPA) focus on educating Individuals, communities, and businesses on how to reduce food waste. In addition, the government also holds a 2030 Champion program to let different companies compete together and encourage them to reduce food waste.

Logically speaking, after 2015, when the policy is implemented, food waste should decline if the procedure is successful. However, our team found that these policies seem to lack mandatory force. Rather than rules or laws, they are more like advocacies and encouragement. Thus, we can tell if the food-waste approach is practical by analyzing the dataset and comparing the amount of food waste before and after 2015.
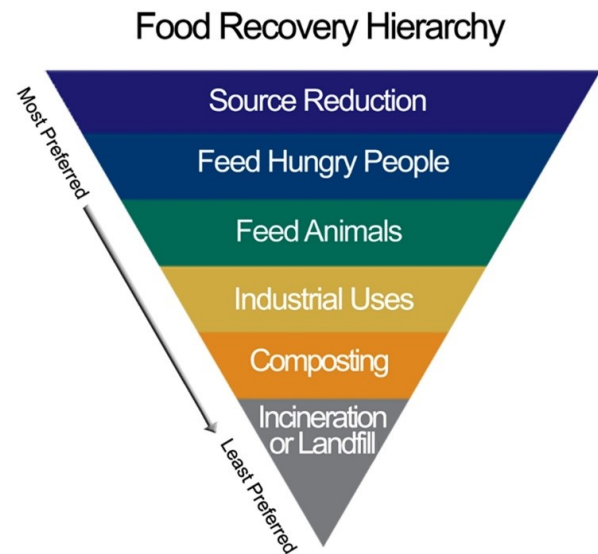

Figure 2: Food Recovery Hierarchy.

4.3. After analyzing data and visualization, what is the reason that some food is wasted the most?

With the data analysis and visualization result, we believe that more stories are behind the result.

To elaborate, it is great to know which food is wasted the most, but it will be more helpful if we can deep-dive into the reason behind it. By investigating the origin that causes the waste of each type of food, related agencies can target the reason and then plan suitable projects to address problems to reduce food waste.

5.   DATA
5.1.   Data Source

The data we are using is collected from ReFED. This national nonprofit organization aims to end food loss and waste in the US food system by advising data-driven decisions. It aimed to follow the policy of the US 2030 Food Loss and Waste Reduction goal announced by the USDA and EPA.

Including the data from 2010 to 2019, the dataset includes every state's food waste and supply situation. Including 425,012 datasets inside, the columns can be clustered into different categories by the following group:
- *Year, State*
- *Sector, Sub_Sector, Sub_Sector_Category*: Places where the data is collected. I.e., Farm, Retail, Household
- *Food_Type, Food_Category*: The food's big and detailed category.
- *Tons_Supply*
- *Tons_Surplus*
- *Tons_Dollars_Surplus*
- *Tons_Waste, Tons_Eaten, Tons_Animal_Feed, Tons_Donated, Tons_Landfilled, Tons_Sewer, Tons_Composted, Tons_Not_Harvested, Tons_Incineration, Tons_Land_Application, Tons_Anaerobically_Digested, Tons_Dumping*: Different ways and methods of dealing with the food waste.
- *CO2eFootprint*: Includes upstream and downstream CO2e footprint
- *Gallons_water_footprint*

The dataset was last updated on January 23, 2021, and has been updated until now. Once the statistic is ready, we could obtain future data for 2020-2022.

5.2.   Data Cleaning

First, we decided which columns to analyze data according to our research question. Since our two research questions are: 1) Which sector wastes the most food? 2)After the US government implemented the food-waste policy in 2015, what were the changes

before and after the launch? We used the following columns as variables:
- *Year, State*
- *Sector, Sub_Sector, Sub_Sector_Category*: Places where the data is collected. I.e., Farm, Retail, Household
- *Food_Type, Food_Category*: The food's extensive and detailed category.
- *Tons_Surplus*

Second, we checked if any data was missing or in a different format. Luckily, although some sector or food type data is named "Available," the data's format is clean and consistent. We only look at the highest hierarchy for analysis of the missing data. For example, for the "Food_Type" column, when it goes down to "Food Category," some corps are shown "Available" since they are crops grown in the production sector, so it means less to fill in the "Food_Type."

6.   DATA ANALYSIS
6.1.   Descriptive Statistics

Table 1: Descriptive statistics of the overall supply and surplus for ten years.

index	tons of supply	tons of surplus
count	425012	425012
mean	17898.904	1828.07297
std	339288.5	17621.6703
min	0	3.92E-06
25%	288.156997	20.5768385
50%	1532.03252	112.890248
75%	6291.19557	638.274723
max	68973561.4	2189269.01

Since the calculation formula of every sector differs, it is hard for us to interpret the result of descriptive statistics. Therefore, we will move on to visualize the data to see more insights into the food waste situation every year and in every industry.

6.2. Visualization

6.2.1. *Food waste sector's proportions.*

After cleaning the dataset, we first aim to know which sector makes the most food waste. By summing up the total food waste that different sectors create. Finally, we visualize a pie chart (Figure 3) showing other sectors' food waste proportions. Surprisingly, the ratio of residential is around 40%, which almost includes half of the food waste sector. It shows that most food waste happens in households after consumption. Danyi (2016) mentioned in her research that although most families feel guilty about food waste and have noticed the negative effect of wasting food on the environment, they still dump food to maintain meal safety and refreshment [10]. Nowadays, people put more effort into food safety, and the viewpoint that wasting food is necessary has become one of the main reasons even though they feel guilty. Therefore, how to effectively reduce food waste in residential may be one of the main points in the future policy. Though the government applied the 2030 Food Loss and Waste Reduction goal in 2015, the approach mainly focuses on reducing landfills. It focuses on how to deal with food waste instead of the origin of causing the food waste. Therefore, if they put more effort into the root, it might work better.
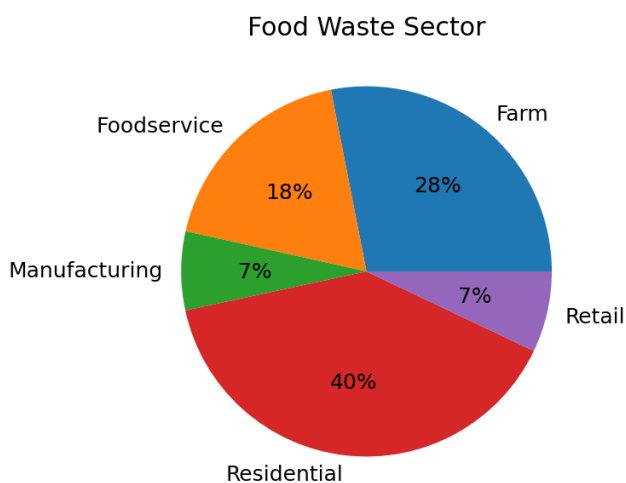
6.2.2. *Food waste type's proportions.*

Secondly, our team wants to discern what food is wasted the most. Therefore, we sort and calculate the sum of each category. Next, we turn the data into a pie chart (Figure 4) showing the ratio of each type of food. As the pie chart shows, the proportion of produce, dairy & egg, prepared food, and dry goods are over 84%.
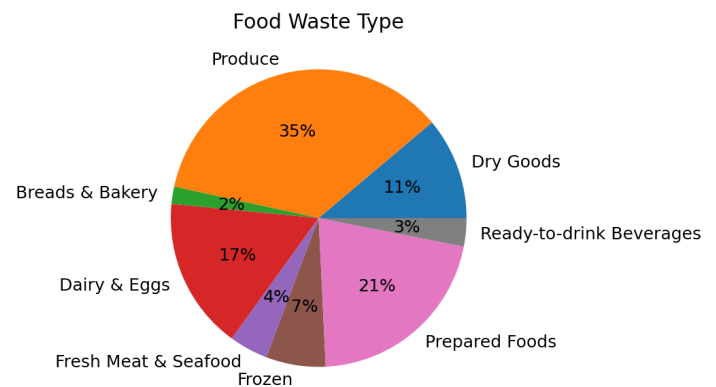

Figure 4: Pie chart of different types of food waste.

Then, we dig more into these four categories and find out the top five foods that are wasted the most in those four categories, and analyze the results below. Our team believes that to solve the food waste issue. The US government should address these foods first.

6.2.3. *Top waste foods of produce and prepared foods.*

To begin with, we started with the "produce" and the "prepared foods" category. In the produce category, as seen in the bar charts (Figure 5), lettuce is the most waste food. Then, we can also see that in Figure 6, deli salad is the most waste food in the prepared foods category. We could see the connection between the two foods: lettuce is salad's main ingredient. To know why they are wasted, we can tell from two aspects: the process of growing lettuce and the increased demand for salad.
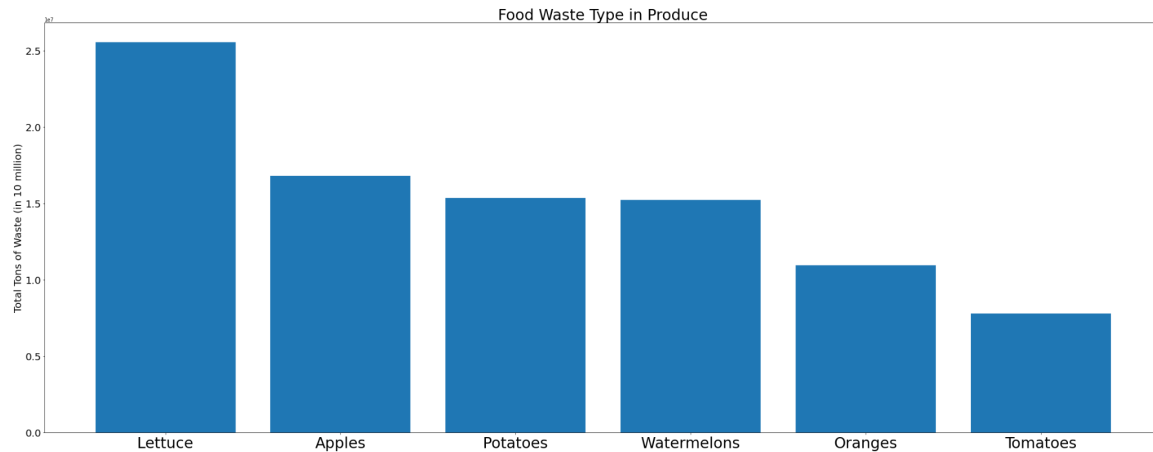

Figure 3: Different sectors' food waste.

Food Waste Type in Produce

Figure 5: Top 5 foods that are wasted the most in the produce category.

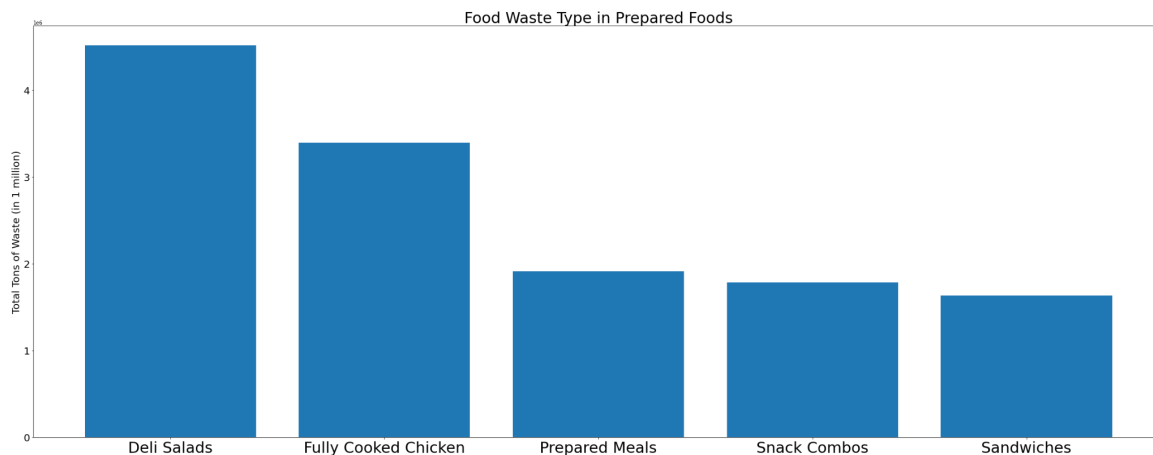Food Waste Type in Prepared Foods

Figure 6: Top 5 foods mostly wasted in the prepared foods category.

Allison Aubrey mentioned in her article that after lettuce is grown and harvested, they are washed and cut to send to the retailer [2]. However, although there are still two weeks before the sell-by date, many lettuces are dumped away due to the lack of time for shipping and checking when arriving at the grocery store. When the lettuce came, the retailers still needed to get those products checked and put them onto the shelves; they needed to ensure that the products were fresh. The long process of shipping and checking often leads to dumping away the lettuce that is not fresh enough when arriving at the store or does not have enough time to maintain freshness before shipping. In other words, due to overproduction and failure to meet the retailer's quality standards, up to 87% of them had been wasted before they got consumed by the customers. However, most large

growers still ignore the problem and over-plant since they do not want to run out of products or regulate the contract between retailers and farmers.

Besides, Stella and Lara (2017) mentioned that fruit and vegetable waste (FVW) in industrialized countries often generates large amounts of waste [4]. Among all of the FVW, fresh-cut salad is causing the most challenging problem. Salad includes up to 50% of the fresh-cut market in the US. Supermarket space for salad has expanded to meet the high demand for this fresh-cut product [8]. The higher the demand for salad products, the higher the food wastage derived. This phenomenon eventually increases the need for producing and growing salads' main ingredient-lettuce.
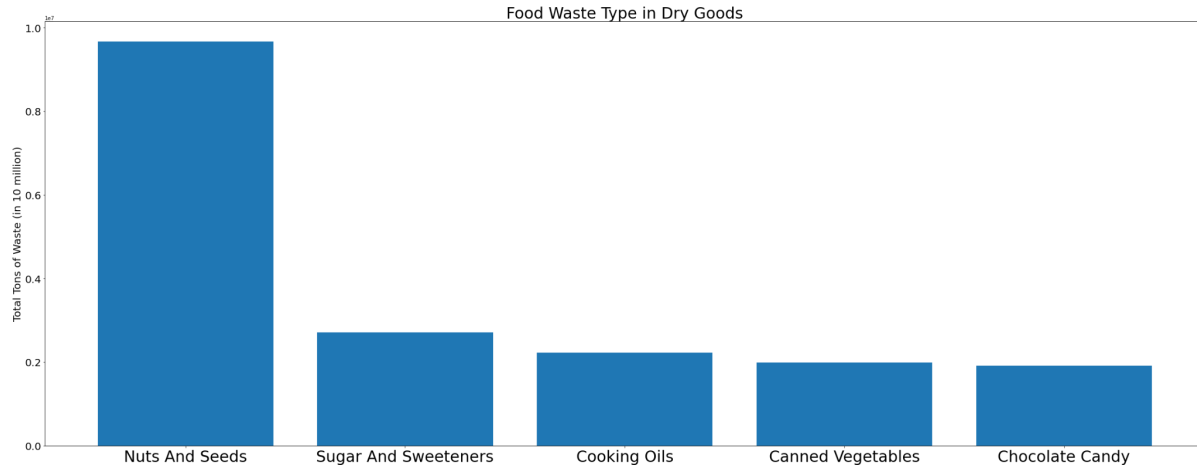
Figure 7: Top 5 foods that are mostly wasted in the prepared dry goods category.

6.2.4.   *Top waste foods of dry goods.*

Figure 7 shows that the foods most wasted in the dry goods category are nuts and seeds. One of the major reasons is related to producing process, which is the absence of proper on-farm drying facilities (Rezaei & Liu, 2017) [11]. More specifically, nuts need to be dehydrated after harvesting so people can preserve them easily.

However, some farms lack professional drying equipment. Thus, they use the traditional way, which is sun-drying. Still, when the weather change suddenly or the humidity change, those nuts will be compromised. As a result, nuts and seeds with higher moisture content lead to contamination. Furthermore, those wet nuts will with mold and toxins during storage, and once contaminated nuts are put with fine nuts, they are infected with their mold by the other nuts. Eventually, those nuts lose their quality, food safety, and economic value.

To conclude, it is crucial to train and facilitate farmers with tools to measure the moisture content in seed and dry nuts with more efficient approaches. For example, hot air, fluidized bed, infrared and solar should be considered when formulating solutions to reduce losses in the nut sector.
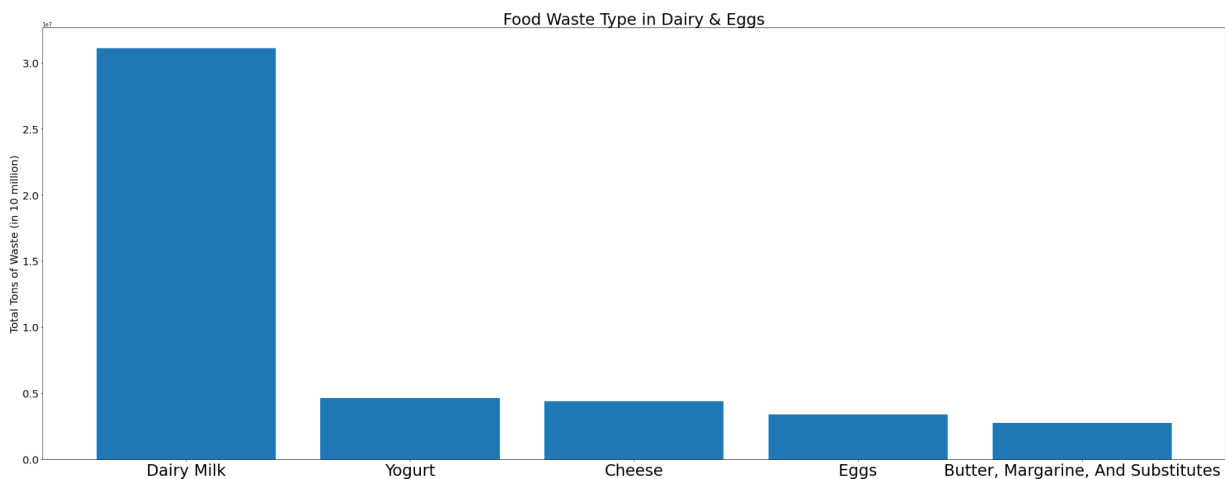

Figure 8: The bar chart of the top 5 foods that are mostly wasted in the prepared dairy and eggs category.

6.2.5. Top waste foods of dairy and eggs category.

Figure 8 shows that milk is the most wasted food in dairy and eggs. Hence, our team researched why people wasted milk so much compared to other dairy products in dairy and eggs. According to NIH, the major reasons milk is wasted are misunderstanding date labels, poor planning of purchases, spoilage before consuming products, and improper storage [6]. To sum up, compared to other food, milk has a higher standard for preserving environmental conditions. Unlike some other food, milk has to be always in low-temperature conditions, which increases the difficulty of preservation so that consumers would spoil lots of milk because of poor preservation.

On the other hand, compared to other food, milk has a relatively shorter shelf life. That is, if farms produce milk without accurate plans and market needs calculation, surplus milk will be produced and expire. Moreover, customers sometimes buy food with poor planning. Honestly, this is not an issue that only happens to milk but also other food. Nonetheless, milk's expiration date is way shorter than other food. Generally, the milk we buy from the market can only be preserved in the fridge for less than a month. Therefore, once people buy milk without checking actual consumption, customers can encounter the expiration issue easily.

Figure 9: Line graph of food waste from 2010 to 2019.

6.2.6. Food waste by years.

For the second research question, our team wants to research the effectiveness of the food waste policy that was implemented in 2015. However, after we sum up all food waste by different years, we found that the amount of food waste has been increasing yearly. Even after 2015, when the government applied the policy, we still observe that food waste has

increased dramatically. Therefore, our team believes the validity of the food waste policy is still under verification. On the other hand, Figure 9 shows that from 2016 to 2019, though food waste did not decline, it held at the same tons. Could it be the benefit that comes later after the policy was implemented in 2015?

To take a deeper look to see whether the policy works, we then compare the food waste type between

2015 and 2016. As Figure 10 shown, the ratio of every food waste type is similar in both years. However, in 2016 the tons of food waste were higher than in 2015, especially in the produce sector. We could assume that the policy has yet to show its effects. Compared to Figure 9, we could also assume that the situation stays the same in the further year. Therefore, although we still need more data to show whether the policy works in these years, it is better to pay more attention to the produce sector to stipulate policy.
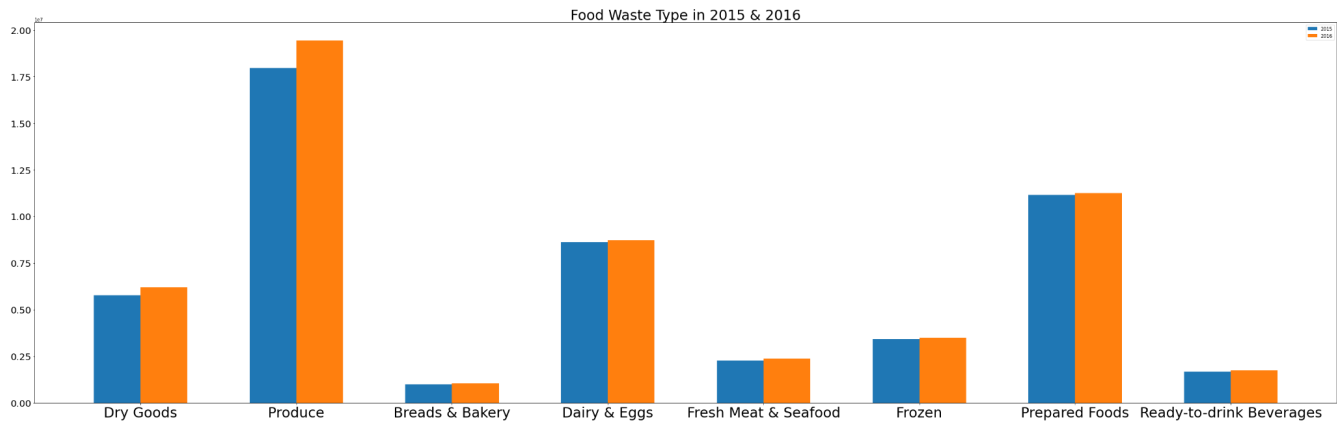

Figure 10: Food waste difference between 2015 and 2016.

7. CONCLUSION

After analyzing and visualizing the dataset, our team extrapolates these conclusions.

7.1. Farms and residential are the main sectors of food waste.

First, almost 70% of food waste comes from farms and residentials. The US government should focus on these parts priorly to reduce food waste. Farms account for almost 30% of national food waste. Farmers need to consider the types of crops they produce on farms. For example, instead of producing surplus lettuce and apples that are wasted the most, probably choose other fruits and vegetables to plant. However, due to the whole structure of the supply chain of salad, it is still challenging to change. Therefore, the following approach will be to find ways to reduce the over-planting problem. For instance, using locavores may be one of the future solutions.

Besides, educating citizens about reducing food waste is paramount because 40% is from residentials. Some foods in residential fields are processed, which means those foods cost more than just produce them. The thoughts of wasting food are necessary and unavoidable and need to be changed and educated. However, advocating and educating lack obligations, so incentives and penalties will be a more effective way to force citizens to reduce food waste.

7.2. Issues of specific food categories should be given higher priority in the policy.

According to the pie chart of different food types, 84% of food waste comes from produce, prepared foods, dry goods, and milk & eggs. After analyzing different categories, we sorted the top 5 agricultural and processed products that were most wasted from 2010 to 2019. Therefore, to reduce food waste effectively, issues of these foods category should be given higher priority.

7.3. Poor purchase plans and production plans lead to food waste.

After looking up several articles, we find why some foods are wasted the most in specific sectors. That is lettuce, salad, nuts, and milk. We consider there are two major reasons. The first one is bad residential food habits. To elaborate, poor purchase plans lead to expiration. As mentioned above, people sometimes throw food because they fear spoiled food and food poisoning. Take lettuce and milk as an example. People throw them away once they are close to or after the expiration date. However, if citizens can think ahead before buying a massive portion, it can significantly reduce food waste, especially food with a short shelf life.

Another reason is poor producing plans and preservation techniques by farms. More specifically, food is thrown away by insufficient quality, overproducing, and spoiling before delivering to markets. As mentioned above, 87% of lettuce is wasted because of bad quality and excess. Hence, we believe farms or governments should focus on producing plans and try to refine them. It is a pity that farmers pay time and effort to plant crops but end up throwing them away, not even making it to the markets. Regarding nuts and milk, our team believes farms should enhance their preservation method. These foods need higher standards to keep them fresh and prevent spoilage. Thus, better storage equipment and techniques can help farms reduce food waste before shipping to markets.

7.4. The policy has yet to have a noticeable effect now.

Lastly, judging from the line graph of the food waste amount from 2010 to 2019, the food waste amount still went up after 2015 when the policy was implemented. Accordingly, our team does not think the policy is feasible for now. That means the US government has to exert a stricter approach to reach the goal set in 2030.

8. RESEARCH RESTRICTIONS & FUTURE SUGGESTION

8.1. Research Restrictions

8.1.1. The calculation formula of the dataset is different.

Due to the dataset's resources, although some data sets are in the same column, they are collected in different methods. In the column "Food Waste," calculating the tons of waste differs for every sector. For example, in the "Farm" sector, the formula is:

Tons of Surplus = Tons Never Harvested + Tons Left Behind After Harvest + Tons Packhouse Losses + Tons Unsold Buyer Rejection

In the sector of "Retail," the formula is as follows:

Tons of Surplus = Tons Purchased by Retailers - Tons Sold

Every sector has its way of calculating and contains different elements and columns due to the sector's characteristics. Therefore, it is hard to compare the supply and surplus within the different sectors and do further analysis.

8.1.2. The coverage date of the dataset still needs to be completed.

Since the dataset does not contain data after 2020, it is hard for us to know the current circumstances for food waste. Besides, the world pandemic, COVID-19, broke out in 2020, significantly changing people's living and consuming habits and behavior. Therefore, if we could obtain the data for these three years, we could discuss the food waste situation further. Besides, once we obtain the data, we could also measure the policy process and see whether we are moving forward to the goal of reducing 50 percent of food waste per person in 2030.

8.1.3. We still need more information and research to prove the effectiveness of the policy launched in 2015.

We only have the dataset until 2019. According to the visualization and insight that we made in the previous section, there has been no significant change after 2015. The total tons of food waste remained the same and rose in 2015. Whether the policy does not work or it may not be long enough for it to be effective. We cannot make an assumption here without further document or paper research. Therefore, once more data about food waste from 2015 to 2019 and papers researching the policy come out, we can look deeper into the reason and discuss more.

8.2. Future Research
8.2.1. *Separate the sectors to dig more into the specific surplus and supply.*

Since the surplus calculation differs for different industries and sectors, it will be an excellent way to focus on one specific sector and dig more into it. Take the "Farm" sector as an example. The dataset includes tons of wasted food and how they deal with the surplus, such as feeding animals, donation, biomaterials processing, or sewer. By understanding the breakdowns of how the surplus is built, we can further find methods to reduce the surplus in this industry. This way, methods and solutions can be built according to each industry's situation and might have more insight into this policy.

8.2.2. *Analyze the current data to see how much the current process has reached the goal.*

The policy aims to reduce 50 percent of food waste in 2030. It has already been seven years since the policy was launched. If we could obtain more data about the project's milestones before 2030, then we could evaluate the result of the policy now and see how far we have reached the goal. Another way is that we can still analyze the percentage now and make predictions for the future to see what the potential food waste will be in the upcoming years. This will be the field of machine learning, and we encourage people to try and predict the model with the dataset.

9. TAKEAWAYS
9.1. Not every data in the dataset are helpful.

When we started the project and downloaded the dataset from ReFed, our team thought we could use the dataset directly. However, after reviewing the dataset, we found the content is chaotic and too massive. There are over 400,000 rows in the dataset; some are unnecessary or obsolete. For instance, while the retailed group has two subgroups, the farm only has one. Thus, we realize that we have to choose only the same group-level data we need and clean the dataset to continue more analysis and visualization.

9.2. Notice the background of how the dataset forms.

During the discussion and selection data, we found that some data seems inconsistent. Therefore, we returned to the website where we downloaded the dataset and found the reason. We realized that for the sum of the food waste, every category has its formula to calculate the result. It will be unfair to compare the details of different categories. Thus, we finally decided only to use the final result, total food waste, to compare and further analyze. We learn that when choosing and reviewing a dataset, it probably takes a minute to observe the origin of the data and how it forms.

9.3. The policy does not make that easy to practice especially lacks obligation.

At the beginning of the project, we thought that the policy being implemented in 2015 would help reduce food waste in the US. Still, during the process, we scrutinized the policy, and three of us thought that instead of calling it policy, it is more like an event or encouragement. Sometimes, even laws and penalties are useless to citizens. How is a policy without enforcement can be effective? It is nice to have a goal, but our team still thinks the law force for essential plans and project is necessary.

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