PREVIEW PAPER: ABOVE AVERAGE

This team also has responses for all three questions. The team has a good summary and includes specific results. For question one the team had a novel idea to break the state up into regions based on food bank locations. Their use of food groups in question two is also an interesting approach. The team examined a wide variety of options for the third question, but their approach was similar to that used by ReFED. With respect to questions one and two, this team had one of the more creative approaches seen by the pre-triage judges. Finally, the team did an excellent job of including both references and citations and did a great job of documenting their work.

Chomping Down on Food Waste

Team Number: 10691

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1 Executive Summary

Food waste is a significant problem worldwide, specifically in the United States. It affects the economics of the food supply chain and the environment. Food waste is created by consumers and retailers. For consumers, food waste is based on how much food they buy versus how much they actually consume, which varies from person to person. As food waste grows, so does the need for landfills, garbage collection, manpower, and equipment. Furthermore, decomposing food produces methane that adds to the greenhouse effect.

For retailers, when food and transportation are wasted, the resources associated with them are also wasted. Food waste for retailers also wastes money. Highly perishable foods with different expiration dates are inherent to the supply chains of the consumer and retailer. Spreadsheet modeling the relationships between variables helps demonstrate the functions and calculate the abilities of the software.

We were tasked to create a mathematical model to determine if Texas could feed its food-insecure population with the wasted food generated in the state over a year. Our model was first created to find the total amount of food Texas wastes. In order to find the amount wasted, we needed to add the food waste of every consumer and retailer in the state. We found a source that broke Texas into 17 groups based on the locations of food banks. It was determined that with the total amount of food wasted, Texas could only feed approximately half a million people, 3 meals a day for one year. Texas could not sustain its 4,234,340 food-insecure citizens.

The next problem was to create a model to determine how much food waste is generated in a household in a year. We were given four household examples to help us prove our model. These included a single parent and a toddler with an annual income of $20,500, a family of four (two parent, two teenage children) with an annual income of $135,000, an elderly couple living on retirement with an annual income of $55,000, and a single 23-year-old, annual income of $45,000. We used a Microsoft Excel spreadsheet that provided us with the average amount consumed per member in a household. We also used another spreadsheet that gave us average amount of money spent on food based on salary. We discovered that each household wastes 36.8% on average of the food it purchases annually.

Finally, we researched models to help us decide how to repurpose the maximum amount of food waste in our state. We found a model that showed the cost and benefits of food repurposing in the nation. Then, we used a percentage of that cost based on the percentage of the United States population that Virginia holds. We found those that would work best for the state with minimum cost and maximum benefit therefore it would be possible for the state as a whole to repurpose food waste and benefit economically and financially.

Contents

2 Problem 1: Just eat it!

2.1 Restatement of the Problem

The problem asks us to do the following:

- Build a mathematical model to determine if a state could use and apply the model to feed its food-insecure population using the wasted food generated in that state
- Determine the mathematical model's impact on the state of Texas

2.2 Assumptions

- The previous year's data on income spent on food is constant for the future year's data.
  Justification: The amount of people whose income would change on a year-to-year basis is too small to consider as a data point or shift
- The wasted food generated in a state will be accepted and consumed by the food-insecure population.
  Justification: Preferences for food vary from person to person, but the differences between people are insignificant enough to ignore.
- We will assume that the state will try to feed its food-insecure population on a year-to-year basis.
  Justification: Our data is based on yearly averages and amounts, so a yearlong time period is an accurate window to interpret our data with.
- The average food consumption for the average American can be extended to the average Texan.
  Justification: Amount of food consumed varies from person to person, but to create a model for every person individually would be too inaccurate.
- According to the "Texas_food_data" spreadsheet, the average meal in Texas is $2.59. This average meal will be extended to $2.59 per meal per county.
  Justification: The spreadsheet gives us the average cost of a meal in the state of Texas, so the average will be close to the actual price of a meal in that county due to the principle of normal distribution.
- We found that Americans consume 84% of food bought, therefore they waste 16%, and this data will apply to Texas as well.
  Justification: If the average American does this, then it is fair to assume that the average Texan citizen will do this as well, according to the law of normal distribution.
- The "North American food loss data" spreadsheet data is close to the same for the state of Texas.
  Justification: Without knowing the food loss data for Texas, this data is as accurate as can be without doing our own surveys and field research.
- Food-insecure people lack, yet require, three meals per day.

Justification: Meals per day may vary, but three meals per day is a common concept and practice, and are required for nutritional value.

2.3 Developing the Model

We began our model by considering a two-level supply chain. The two levels of the supply chain are the consumers and the retailers, which both produce some amounts of food waste. According to Feeding America, there are seventeen food banks in the state of Texas, which is how we decided to derive our seventeen groups. Each food bank covers a certain amount of counties, ranking from three counties served to thirty-two counties served. The variable *G* is the number of groups, the variable FW is the food wasted, the variable r is the retailor, the variable c is the consumer, and the variable *t* is the period of time being investigated, which we assumed to be one year (Somkun, 2017).

The total food waste of a period t is the food waste of the retailer in the given time period plus the food waste of the consumer in a given period of time. This is stated in the following equation (Somkun, 2017):

$$FW_t^{sc} = FW_t^r + FW_t^c$$

The food waste equation for the retailer at time t, FW_t^r, is found by using the data provided by each individual state. We took the percentage of groups of food (e.g. cereal, meat, etc.) and multiplied each by the state receipts for that specific food group. This gave us the waste per individual food group. After summing up the waste from each food group, we were able find the total food waste at the retail level.

If one decides to divide a state into groups, one can use the following food waste equation for each group (Somkun, 2017):

$$FW_t^g = B_t^g - C_t^c$$

The food waste formula for each group in a time span, t, is found by subtracting the food consumed in that time span from the food expenses in that same time period. These can be found by applying the given state data of median household income, number of households per group, food expenses per household, food expenses, food consumed per household, and food consumed.

The total food waste at the consumer level in a time period t, FW_t^c, can be found by the following equation (Somkun, 2017):

$$FW_t^c = \sum_{g=1}^{G} FW_t^g$$

2.4 Input of Model for the State of Texas

Texas was used to validate our model. We split up Texas into 17 groups based on the service area of the 17 food banks, as showed in Figure 1.

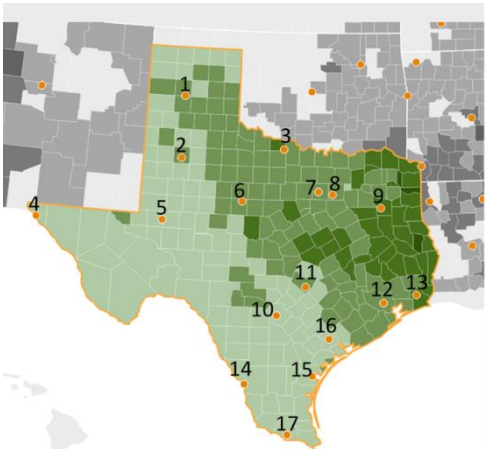

Figure 1-Image from http://map.feedingamerica.org/county/2015/overall/texas

We calculated the average median household income, average number of household, food expenses per household, and food consumed per household for each group. Food expenses per household and food consumed per household were then multiplied by the number of households to calculate the food expenses and food consumed for each group. To find the food wasted, we found that the average American consumes 84% of the food bought, meaning the average American wastes 16% of the food purchased (Backman, 2016). The food consumed was subtracted from the food expenses to calculate the monetary food waste for each of the 17 groups.

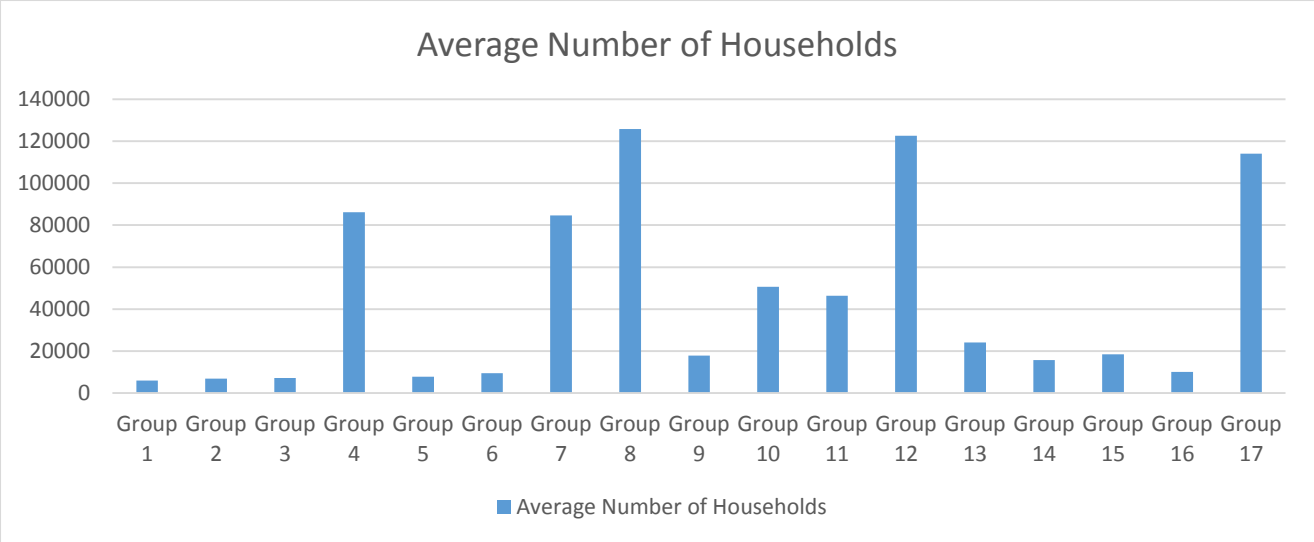

Figure 2-Graph made in Microsoft Word. Displays numbers of households

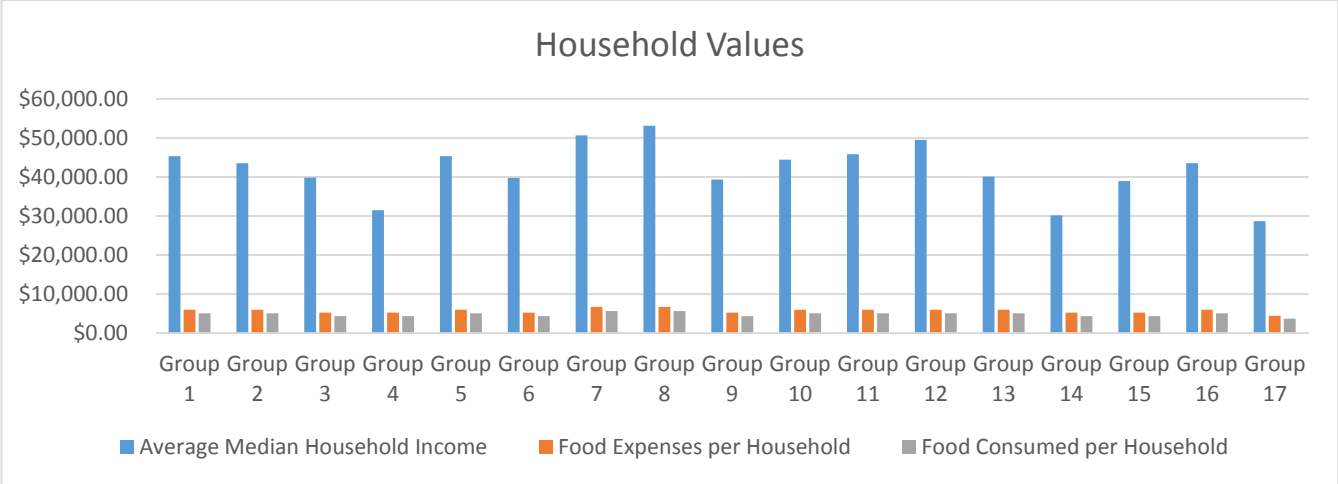

Figure 3-Graph made in Microsoft Word. Display household values

Figure 4-Graph made in Microsoft Word. Displays the values for food expenses and food consumed.

After calculating the above information, we were able to determine the total monetary food wasted in each of the 17 groups.

Groups	Monetary Food Waste
1	$5,719,599.21
2	$6,731,889.56
3	$6,083,648.43
4	$72,018,891.68
5	$7,589,594.64
6	$7,981,029.44
7	$91,273,845.42
8	$135,659,677.96
9	$14,957,313.58
10	$48,804,556.68
11	$44,724,269.50
12	$118,146,871.04
13	$23,319,679.68
14	$13,187,619.48
15	$15,383,154.40
16	$9,687,675.52
17	$80,899,170.24
Total	$702,168,486.40

After calculating the total monetary food waste for the consumers of Texas, we then found out the total monetary food waste for retailors in the state of Texas. By using the given data for North America,

Groups of Food	Supermarket Retail Losses and Waste (%)	State Receipts ($)	Losses and Wastes
Cereals	2%	$439,449,000.00	$8,788,980.00
Roots and Tubers	7%	$131,890,000.00	$9,232,300.00
Oilseeds and Pulses	1%	$656,559,000.00	$6,565,590.00
Fruits and Vegetables	12%	$1,591,210,000.00	$190,945,200.00
Meat	4%	$11,264,767,000.00	$450,590,680.00
Fish and Seafood	9%	$17,722,000.00	$1,594,980.00
Milk	0.5%	$1,848,140,000.00	$9,240,700.00
Total			$676,958,430.00

The total food wasted, is determined as followed:

$$FW_t^{SC} = FW_t^r + FW_t^c$$

$$FW_t^{SC} = \$676{,}958{,}430.00 + \$702{,}168{,}486.40$$

$$FW_t^{SC} = \$1{,}379{,}126{,}916.40$$

The "Texas Food Insecurity" data given in the Excel spreadsheet states that the average cost for one meal in Texas is $2.59. Based on this, the monetary food wasted at the consumer and retail level can provide 532,481,435 meals. Being that the average meals per day is three,

$$\frac{\$1{,}379{,}126{,}916.40\ \frac{food\ wasted}{year}}{3\frac{meals}{day} * \$2.59\frac{cost}{meal}}$$

the food wasted can provide three meals a day for 486,284 people

2.5 Conclusion

It is assumed that the money wasted at the food and consumer level can be avoided to be repurposed to aid food insecure peoples of the state of Texas. If this were the case, we would be able to use that money to pay for three meals a day for a year for 486,284 people. Based on the insecure population of Texas being 4,234,340 people, it can be concluded that the food wasted at the consumer and retail level cannot be enough to provide three meals a day for each food insecure person. However, reducing the total food waste in the state of Texas can still help a great amount of people who are food insecure.

3 Problem 2: Fixing "Food Foolishness"

3.1 Restatement of the Problem

The problem asks us to do the following:

- Find the amount of food waste a household generates in a year based on their traits and habits.
- Demonstrate how our model works by using 4 different household examples.

3.2 Assumptions

- Gender is not included in our model.

  Justification: There is no substantial evidence to suggest that females consume more or less food compared to males. Not enough information was provided to determine whether or not the people in the household were any specified gender.

- Our model should not be considered accurate above a $500,000 annual income.

  Justification: There is no reason to believe that the model does not accurately predict the amount of money spent on wasted food. However, there is not enough data on households that make over $500,000 for us to be able to say whether the model is accurate enough.

- Our model predicts the average food waste as compared to household salary for average Americans.

  Justification: Though there can be variation in data, the data we have collected represents average Americans.

3.3 Developing the Model

We began our model by determining the average consumption of food in 4 households, given to us in the problem. We will attempt to use the following 4 households to determine whether or not our model is accurate:

Single parent with toddler	$20,500
Elderly couple, living on retirement	$55,000
Family of 4 (2 children, 2 adults)	$135,000
Single 23-year-old	$45,000

Using the "ConsumerBehaviorBasedon Income" MS Excel spreadsheet, we determined the average amount of money spent on food as related to household income. Using information from *Wasted: How America is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill by Dana Gunders*, we got the following information:

Percent of Food Lost based on Product	
Product	**Percentage**
Dairy Products	20%
Fruits	52%
Grain Products	38%
Meat	22%
Vegetables	52%

We determined that the average American Household wastes 36.8% of the food it purchases using the formula:

$$0.368 * Average\ Anual\ Food\ Expenditure\ by\ Wage\ Bracket = Amount\ of\ Money\ Spent\ on\ Wasted\ Food$$

Using the income of the household as the x-value, and the money spent on wasted food as the y-value, we plotted a scatterplot and used a quadratic regression to find an equation that would become the basis of our model. The equation, that has an R^2 value of 0.9997, reads:

$$(-6 * 10^{-8})x^2 + 0.0291x + 1058.6$$

The R^2 value is the closest to 1 of all the regressions possible, which means that this equation is the line of best fit.

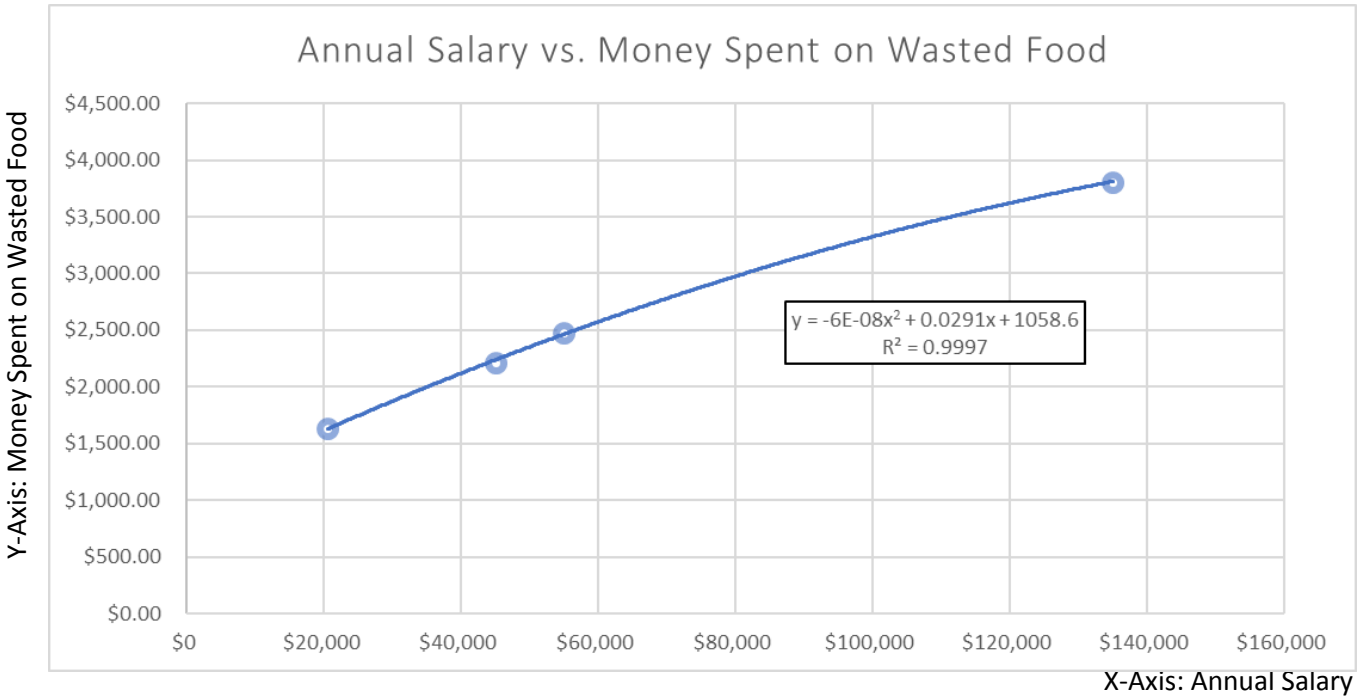

Figure 5-Source: Excel Spreadsheet with plotted scatterplot and quadratic line-of-best-fit of our data

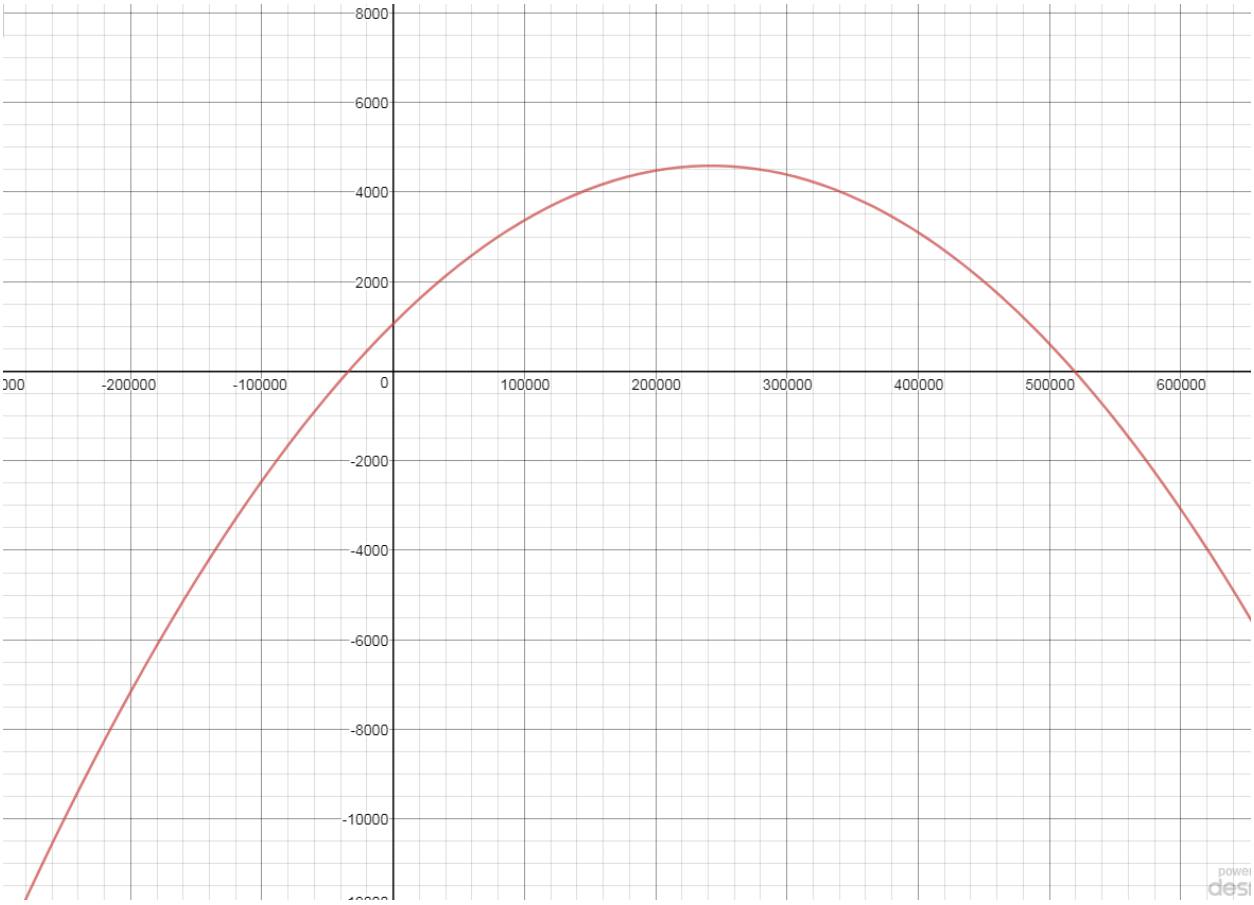

Figure 6-Graph of Mathematical Model on Desmos.com with an input of the (-6〖10〗^(-8)) x^2+0.0291x+1058.6 function*

3.4 Verifying the Model

When we input the amount of money each household has in the function, the model will tell us the average amount of money that the same household will spend on the food they will waste. Using this process, the model helps us to determine the following information:

Amount of Money Spent on Wasted Food per Household	
Household	**Money**
Single parent with toddler	$1,632.82
Elderly couple, living on retirement	$2,479.95
Family of 4 (2 children, 2 adults)	$3,809.17
Single 23-year-old	$2,218.30

4 Problem 3: Our "Hunger Game Plan"

4.1 Restatement of the Problem

The problem asks us to use mathematical modeling to do the following:

- Determine how the state of Virginia can repurpose the maximum amount of food at the lowest cost.
- Quantify the cost and benefits associated with our choices.

4.2 Assumptions

- Although the data we researched applies on a national perspective, it will also apply to the state of Virginia.

  Justification: Since the data was gathered from the entirety of the United States, then taking a piece of the country will also keep the data valid.

- We assume that since Virginia is 2.58% of the United States population, that it will be responsible for 2.58% of the cost of the measures we want to suggest.

  Justification: Virginia holds 2.58% of the population of the country, so it will be responsible for almost the same amount of waste, and the difference between the actual amount of waste it is responsible for and the amount of waste we assume it is responsible for is miniscule, and therefore not important enough to include in calculations.

4.2 The Model We Used

Our model was created by ReFED as an argument for reducing food waste in the United States in a cost-effective and profitable manner (Reducing Food Waste). We used their cost-benefit analysis to decide what methods the state could use to cut down on food waste. These methods include consumer education campaigns, standardized date labeling, waste tracking and analysis, and packaging adjustments. We picked the options that would offer the most benefit, and least amount of cost.

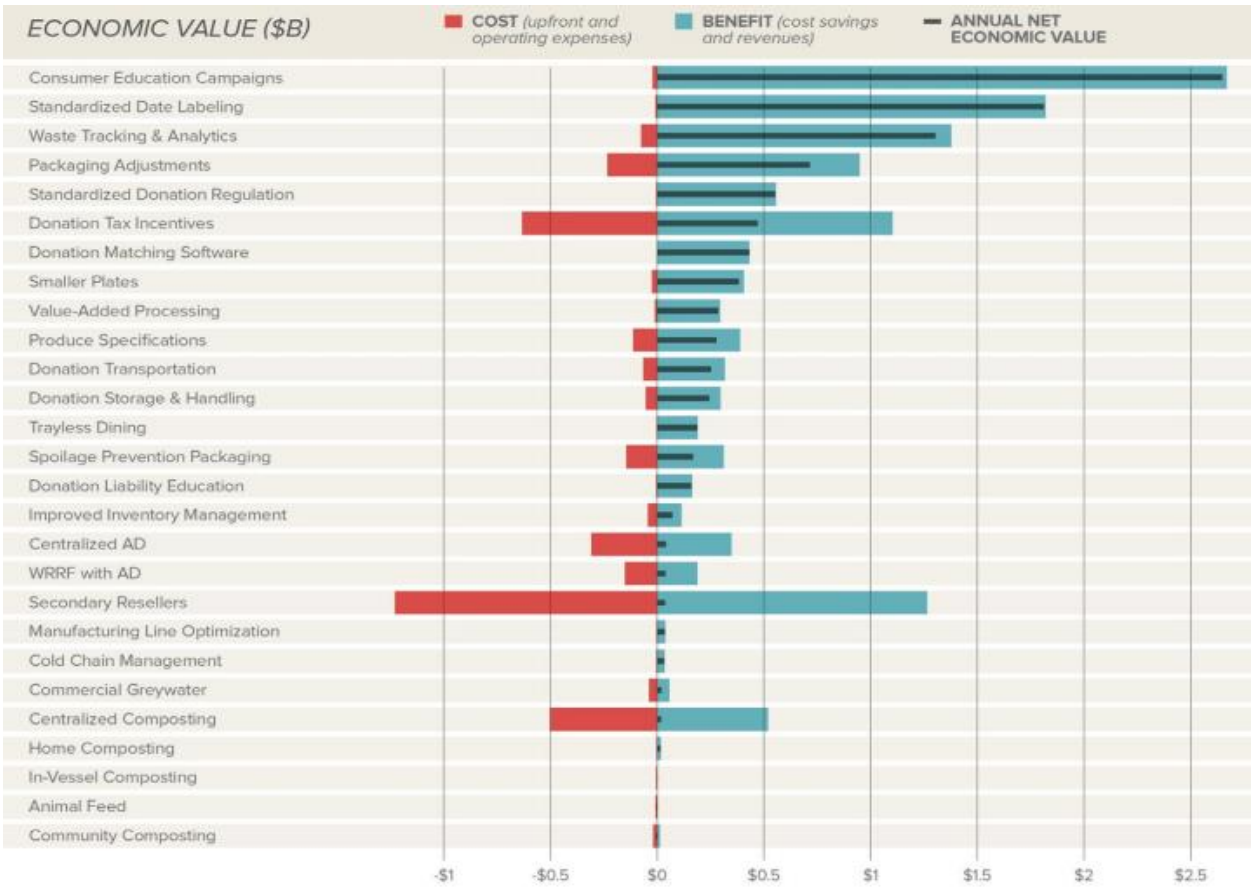

Figure 7-Source: https://www.refed.com/downloads/Economic_Analysis.pdf

4.4 Our Choices for Virginia

We chose the following options for Virginia based on their cost-benefit relationship being the most desirable. The options we chose were what we saw on our model to be the most effective in reducing the amount of wasted food in a cost-effective manner.

Method	Consumer Education Campaigns	Standardized Date Labeling	Waste Tracking and Analysis	Packaging Adjustments
Cost	$50,000,000.00	$5,000,000.00	$10,000,000.00	$250,000,000.00
Benefits	$2,600,000,000.00	$1,800,000,000.00	$1,400,000,000.00	$900,000,000.00

Figure 8-Our estimates of the amounts of cost and benefit from the model

These options were the most desirable because their benefits were deemed to outweigh their costs the most. Our figures for the costs and benefits are estimates, because the model is not labelled on the x-axis accurately.

5 Conclusion

In the models we created we demonstrated the amount of food waste based on several different factors that include household, income, business, etc. The first model allows you to determine how much all retailers and consumers in the state of Texas waste annually. From the amount wasted we came to the conclusion that only approximately half-a-million of the food-insecure population could survive for a year with three meals a day. This would not support all of them.

We then found a model to help us determine how much a household wastes food based on size and income. We determined that each household wastes 36.8% of the total food they purchase each year. Our model allows a reader to determine how much they waste, up to a salary of $500,000. In our last problem we discovered a model that allowed us to determine the best possible ways for the state of Virginia to repurpose their wasted food with maximum benefit and minimum cost.

5.1 Strengths

- The model of problem one can calculate the monetary amount of food waste for any area at any time. The smaller an area of focus is, the more accurate the model for problem one is.
- The model for problem two is accurate for any household annual income from $0 to $500,000.
- The model for problem three's benefits greatly outweigh the costs.
- Using the data from problem three could be applied to Virginia and the United States as a whole.
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5.2Weaknesses

- The model of problem one requires extensive gathering of data from the location area, such as the number of households, the population, and the food-insecure population.
- For larger areas, the model of problem one uses averages to calculate the food waste.
- The model of problem 1 did not take into account citizens on governmental assistance or donations received from charitable causes, such as people on WIC, people on SNAP, or people who go to food drives at their Church.
- The model of problem 1 assumed that all Americans waste 14% of food bought, regardless of income, race, or gender.
- The model of problem 1 assumes that money spent on wasted food can be avoided and repurposed to the food insecure.

6 References

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