# Oklahoma State University Waste Stream Analysis

Spring 2017

Caleb Anthony, Destiny Barker, Kevin Courtney, Thomas Spadea, Dusti Thompson

## Contents

## **Literature Review**

Solid waste, as an irrefutable fact, follows human colonization wherever it goes. Since humans ceased their nomadic tendencies and began stationary civilization, solid waste has been an issue. Early civilizations did not have an effective system to rid themselves of their waste and simply threw it in the floor. In Troy during the times of the Ancient Greek, things like bones, food waste, and broken pottery would be thrown in the floor of their dwellings. Once the smell became intolerable, a fresh load of soil would be brought in to cover the waste, and the process would continue for centuries (BASD, 2017). Once the pile-up of waste and soil became too high, instead of removing the rubbish, the roofs and doorways of the house would be altered to accommodate for the new height of the floor (Sustaining Our World, 2017).

Humans have come a long way since the times of Ancient Greece. We now have a sophisticated waste system that involves disposing the waste in landfills. Most of these landfills are periodically covered with layers of soil, similar to the tactics of the Ancient Greeks. There is some concern, though, about whether or not landfills will continue to be sustainable with the increasing human population. The average American currently produces about 4.3 pounds of waste per day. This means the average American produces their weight (180 lbs) in waste every 6 weeks, which also means the average American produces over twice as much waste than people in other developed countries (Thompson, 2012). In total, Americans produce as much as 258 million tons of waste each year. 258 million tons equates to over 707 empire state buildings. About 134.1 million tons (52%) of this waste finds its way to landfills, 90.4 million tons (35%) is recycled, and 33.5 million tons (13%) is burned to produce energy (Payne, 2017). According to the Environmental Protection Agency (EPA), about 52% of municipal solid waste (MSW) could be recycled and 28% is made of organic matter such as food, yard trimmings and wood. This organic matter is material that could be composted and used by farmers (EPA, 2017).

Organic matter in landfills is problematic. Under normal conditions, organic matter decomposes because the conditions are aerobic, which means there is enough oxygen to sustain the bacteria that break down the matter. In landfills, there is not enough time for the organic matter to break down before more garbage is put on top of it. Soil is also periodically layered on top of most landfills, and this creates anaerobic conditions, or conditions that do not have the amount of oxygen necessary for the decomposition of organic matter. This buildup of organic matter leads to an increase in the production of methane, one of the major greenhouse gases responsible for climate change. According to the EPA, almost 18% of all methane produced in the United States comes from landfills. This amount of methane is equivalent to 110 million US tons of carbon being released into the atmosphere (Piccirilli Dorsey, Inc., 2017).

Advantages of recycling include a reduction in the need for raw materials, or materials that have not been processed. This ensures the sustainability of natural resources for future generations and decreases the amount of stress put on the environment required to produce those materials. Recycling also decreases the energy needed to manufacture goods. This includes a reduction in transportation, machine operations, and human energy used to gather the raw materials (EPA, 2017). Jobs are also created with the implementation of recycling. For every 10,000 tons of waste that is dumped into landfills, 6 jobs are created. For the same amount of waste that is recycled, 36 jobs are created. If the US implements a 75% recycling rate by 2020, this would create 1.1 million new jobs (Bailey, 2017). As the world population increases, the amount of space needed for things like housing development and agriculture also increases. Recycling decreases the amount of space needed for landfills so that area can be utilized in more important ways (Conserve Energy Future, 2017). Recycling is preferred over both simple incineration, which turns the waste into ash and heat, and waste-to-energy incineration, which turns the waste into heat that can be produced into energy. This is because both forms of incineration produce gases that are more harmful to the environment and can be avoided by recycling (EPA, 2017).

Recycling is also met by some challenges. For instance, recycling is not always the most cost effective option. Between the cost of building a new facility, purchasing special trucks for transportation, and the cost of transportation, it is difficult to make money. Sometimes products made from recycled materials are not always the most durable. This is because when products are made from recycled materials, the material used is pulled from a large pile. This could include materials that have been over-used and no longer have the quality of raw materials (Conserve Energy Future, 2017). It is also sometimes cheaper to make products from raw materials than to produce them from recycled substances. This happens to be the case for producing some plastics because the compounds used to make plastic are made during the process of refining crude oil into gas (American Chemistry Council, 2015). Because so much of the compound is already produced, it is cheaper to use the raw materials than to go through the recycling process. One of the most hindering challenges of recycling is that it requires extra effort from the person recycling (Conserve Energy Future, 2017). Products usually have to be clean, which requires washing before disposal. Recycling also requires conscious effort to be placed in the proper bin, an act most people are disinterested in performing because it is much easier to throw away everything into one place instead of 2 or 3. Because of these challenges, recycling may not be the most economical process used to make products, but it is the most sensible decision when considering the sustainability of the earth for future generations.

## Abstract

Replicating the 2013 waste audit performed by Bhuvana Kandula and OSU sustainability, this capstone group audited the trash for a single day, from a variety of dumpsters on the OSU campus. Percentage weight and volume were measured and compared to the 2013 audit. Results were analyzed to recommend potential areas of improvement for OSU recycling.

## Introduction

In spring 2013, a civil engineering graduate student conducted the first waste audit of the OSU Stillwater campus. Six buildings were audited on campus, the purpose of using these buildings was to include dining, offices, classrooms, laboratories, residential, and a combination of two or more. Six bags were taken from each building's dumpster the day before a normal trash collection. The 36 bags were then sorted into 21 categories and weighed. Recommendations from the 2013 waste audit included the implementation of composting due to the high amount of food waste, the reduction of single use material, such as drinking cups and paper towels, education, and the implementation of a more intense recycling program on campus.

**Summary of Intent:** The intent of this paper is to give an account of the 2017 OSU waste audit, compare the data from the 2017 and 2013 waste audits, and make recommendations to further OSU's ambition of being a greener campus.

## Research

To achieve the goal of becoming a greener campus, we must compare OSU Stillwater's recycling and waste protocols with other universities and municipalities. This comparison is to evaluate where OSU Stillwater can improve and what makes other universities and municipalities successful. Below are recycling and waste procedure descriptions for OSU Stillwater, OU Norman, Stillwater, Oklahoma City, and Tulsa.

OSU Stillwater:

OSU Stillwater has two recycling programs on campus: OSU Recycles and Res Life Recycles. OSU recycles is implemented in classroom buildings, dining areas, and outside walking paths. Res Life Recycles is implemented in student housing buildings on campus. OSU recycles takes recyclable paper* and cardboard in one bin, and plastic bottles and aluminum cans in another bin. Res Life Recycles takes recyclable paper, cardboard, clean food cans, and plastics #1-5, all single stream*. Paper and cardboard recycled through OSU Recycles is baled and sold to the highest bidder. Plastic bottles and aluminum cans are taken away by Oklahoma City Waste Management. Recycling from Res Life Recycles is taken to Supporting Community Lifestyles in Stillwater, and sorted there.

Since the 2013 waste audit, the university has tried to reduce the amount of organic waste by composting lawn waste and pre consumer food waste, such as coffee grounds and produce scraps. Lawn waste is used as mulch or is sold outside of the university to be used as mulch or composting. The pre consumer food waste is given to local farmers to be composted and used on their land.

The OSU Stillwater Recycling Department has not conducted a full scale cost/benefit analysis, but it is estimated the program is breaking even. Collecting recyclables does not cost the university any more than if the recyclables were to be sent with the trash to the landfill. The department is mostly paid for by the savings created by diverting recycling from landfills, and the profit on the cardboard, paper, and scrap metals that are sold.

Oklahoma City Recycling:

Average diversion rates are 692 US Tons and include 369 of Newspaper and 206 US Tons of Glass, which are the largest amounts. Total recyclable material is 8,307 US tons that was diverted from the landfill.

| Residential Tons of Resources Diverted From the Landfill ** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Material** | **JULY** | **AUG** | **SEPT** | **OCT** | **NOV** | **DEC** | **JAN** | **FEB** | **MAR** | **APR** | **MAY** | **JUN** | **TOTAL** | **AVG** |
| **Newspaper** | 300 | 274 | 332 | 327 | 365 | 470 | 411 | 323 | 428 | 370 | 404 | 425 | 4,430 | 369 |
| **Aluminum** | 27 | 24 | 30 | 29 | 6 | 8 | 7 | 6 | 7 | 6 | 7 | 7 | 165 | 14 |
| **Glass - Mixed** | 214 | 195 | 236 | 233 | 183 | 235 | 205 | 161 | 214 | 185 | 202 | 212 | 2,475 | 206 |
| **Plastic - Mixed** | 107 | 97 | 118 | 116 | 63 | 81 | 71 | 56 | 74 | 64 | 70 | 73 | 990 | 82 |
| **Tin** | 20 | 18 | 22 | 22 | 19 | 24 | 21 | 17 | 22 | 19 | 21 | 22 | 248 | 21 |
| **Recyclables Total** | 667 | 609 | 738 | 727 | 636 | 818 | 715 | 562 | 746 | 644 | 704 | 739 | 8,307 | 692 |
| | | | | | | | | | | | ***Based on aggregate data from Materials Recovery Facility* | | | |

**Fiscal Year 2016 - Waste Management**

Average residential rates were 27% based on the average times recycling bins were set out taken from the total number of homes enrolled in the recycling program.

| Residential Participation Rate | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **JULY** | **AUG** | **SEPT** | **OCT** | **NOV** | **DEC** | **JAN** | **FEB** | **MAR** | **APR** | **MAY** | **JUN** | **AVG** |
| **Total Homes in Recycling Program** | 174,812 | 174,898 | 174,898 | 174,985 | 174,785 | 175,031 | 175,361 | 175,366 | 175,000 | 175,004 | 174,746 | 178,219 | 175,259 |
| **Recycling Set Out Rate** | 25% | 25% | 29% | 29% | 25% | 31% | 28% | 21% | 29% | 25% | 25% | 28% | 27% |
| **Avg. Homes Set-Out Per Week** | 44,515 | 44,446 | 50,498 | 50,653 | 43,659 | 53,509 | 49,205 | 37,556 | 50,232 | 44,185 | 44,475 | 49,640 | 46,881 |

**Fiscal Year 2016 - Waste Management**

Based on the amount of recycling material collected from the amount of total trash collected 4% of residential refuse was diverted from the landfill. This includes bulky waste as well as recycled material collected from the drop-off facility.

| Tons of Residential Refuse Materials Collected | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Service | JULY | AUG | SEPT | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | TOTAL | AVG |
| Trash | 15,250 | 11,788 | 12,292 | 12,140 | 10,640 | 13,090 | 11,832 | 9,295 | 13,198 | 14,958 | 14,716 | 15,344 | 154,544 | 12,879 |
| Bulk | 3,088 | 1,497 | 1,286 | 2,488 | 1,175 | 1,349 | 1,552 | 1,568 | 2,000 | 4,079 | 2,700 | 2,698 | 25,478 | 2,123 |
| Total | 18,338 | 13,285 | 13,578 | 14,628 | 11,814 | 14,439 | 13,384 | 10,863 | 15,198 | 19,037 | 17,415 | 18,042 | 180,022 | 15,002 |
| Tons of Residential Recycling Materials Collected | | | | | | | | | | | | | | |
| Dual Stream | 667 | 609 | 738 | 727 | 630 | 810 | 708 | 557 | 739 | 638 | 697 | 732 | 8,252 | 688 |
| Total Tons of Residential Materials Collected | | | | | | | | | | | | | | |
| All Materials Total | 19,006 | 13,894 | 14,316 | 15,356 | 12,444 | 15,249 | 14,092 | 11,420 | 15,936 | 19,675 | 18,113 | 18,774 | 188,274 | 15,689 |
| Residential Diversion Rate From Landfill | | | | | | | | | | | | | | |
| Residential | 4% | 4% | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 3% | 4% | 4% | 4% | 4% |

**Fiscal Year 2016 - Waste Management**

Tulsa Recycling:

City of Tulsa recycling collection was 21% based on amount of residential recycling collected from the amount of residential refuse collected. The participation rate was 30% taken from the set-out rate and the total number of households enrolled in the recycling program. This does not include bulky refuse or recycling collected.

**Residential Refuse –** 101,914 US Tons

**Residential Recycling –** 20,903 US Tons (Tulsa Residential Trash and Recycling Center – TRT)

**Calendar year 2016 – Tulsa City of Streets and Stormwater Dept.**

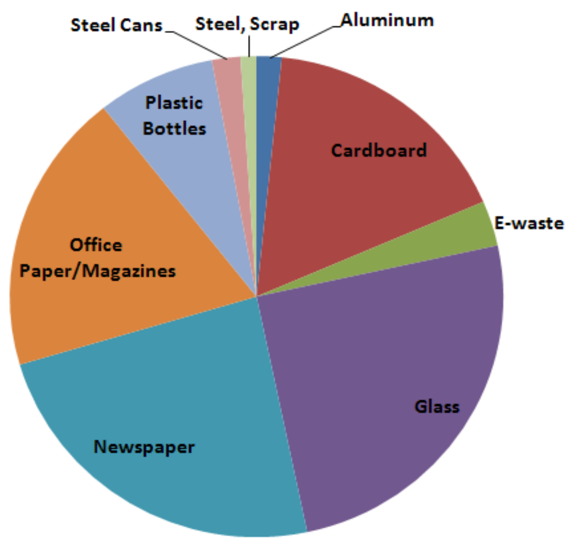
Tulsa Area Recycling – (Metropolitan Environmental Trust – MET)

MET total collection broken down by type of material collected.

| All Depot - Totals | Aluminum | Antifreeze | Batteries (Lead Acid) | Batteries (Household) | Cardboard | E-waste | Glass | Grease-Cooking | Newspaper | Off. Papr/Mag | Oil- Motor | Plastics Bottles | Plast. Bags | Steel Cans | Steel, Scrap |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 72,980 | 1,595 | 17,269 | 19,850 | 754,646 | 135,503 | 1,120,800 | 1,709 | 1,058,860 | 844,253 | 28,227 | 345,163 | 14,696 | 83,359 | 46,220 |

**Metropolitan Environmental Trust 2016**

Graphically, the data broken down by type and amount reveals the majority of recycling material collected was 2.7 million pounds (1,225 metric tons) of Paper/Cardboard and 1.1 million pounds (454 metric tons) of Glass.




**Metropolitan Environmental Trust 2016**

<u>Stillwater Recycling:</u>

The City of Stillwater recycling service diverted 16% from the landfill and had a 57% participation rate from residential collection. It also included a 6% diversion rate with a 7% participation rate.

**Residential Refuse** – 8,578 US Tons

**Residential Recycling** – 118 US Tons

**City of Stillwater – Fiscal Year 2016**

University of Oklahoma:

The University of Oklahoma has an energy program called Crimson and Green. Oklahoma has taken many steps to become a climate neutral university. Their recycling program has a distinct advantage over the Oklahoma State program that, if implemented at OSU, would likely improve our recycling efforts. This advantage is the clear, and easy to understand, labeling of their recycling bins. Their recycling bins are clearly labeled with the type of materials that you can throw into them. They do not look as aesthetically appealing as OSU's bins, but the functionality seems to outweigh the external appeal. Many students we have spoken with report just throwing away their recyclables because it was too time consuming to determine which bins they could throw their trash into (Oklahoma).

Pepperdine University:

Pepperdine University has a recycling program that is recognized nationwide. Perhaps the greatest benefit they have with their recycling efforts is all recyclables are to be thrown in a single bin. Pepperdine then pays a vendor to come pick the recyclables up and sort them offsite. The cost for this may be more than the current Oklahoma State system, but the amount of waste taken to landfills could be significantly reduced. Pepperdine claims to divert 80 percent of its waste from landfills (Pepperdine). They are able to do this because they use one bin that makes it easy for the average person to discard those things they know to be recyclable without wasting time and eventually giving up because they cannot figure out which bin to throw their recyclables into.

The main point we are getting at with improving the recycling efforts at OSU is to make it easier for the consumer to recycle. Whether that be with clearer bins, or having everything be thrown into one bin which is sorted somewhere else instead of by the consumer. Making it easier to recycle is the key to reducing the amount of waste that the university produces.

## Methods and Materials

The 2017 waste stream audit was very similar to the 2013 audit. Six trash bags were collected from the same dumpsters at the same six buildings as the 2013 audit. The six different buildings were the Student Union, Classroom Building North, Physical Sciences (Henry Bellmon Research Center side), Ag Hall, Kamm-Peterson Friend residence hall and Family/Graduate student housing.

The bags were collected on Thursday, February 23$^{rd}$, and held at the OSU recycling center until Saturday when the waste audit was done. Before the audit was done everyone received an Environmental Health and Safety training by personnel from EHS personnel. The audit was performed by members of the OSU facilities management sustainability department, the OSU Environmental Science Club, the SGA Sustainability Committee, as well as this capstone group. The recycling was sorted into the same 21 categories as in 2013 (See Appendix A for categories). All of trash was sorted into their respective categories, and any recyclable materials were taken by OSU Recycling.

The percentage weight for each category was determined by subtracting the weight of the liner and bucket from the tared weight and dividing by the total weight of all 6 bags for that building. We also measured volume in each category by estimating how much of a 5 gallon bucket the waste occupied. The percent weight and volume allowed us to assess how much waste could have been recycled and give us a clue as to what methods would be most effective in terms of increasing diversion from landfill rate for each building as well as OSU in general.

**Results**

Classroom Building North (CLBN):

A total of 58.3 lbs and 100 gal was sorted from Classroom Building North. The largest percentages of weight were taken up by food waste at 33.6% and non-recyclable paper at 12.5%. Plastic bags/film was a significant category taking up 11.8% of the weight and 15.0% of the volume. Corrugated Cardboard and Plastics #3-6 were both significant as they accounted for 15.5% and 12.0% of the volume respectively.


Figure 1: Pie chart representing the percentage of **weight** in each category for Classroom Building North.

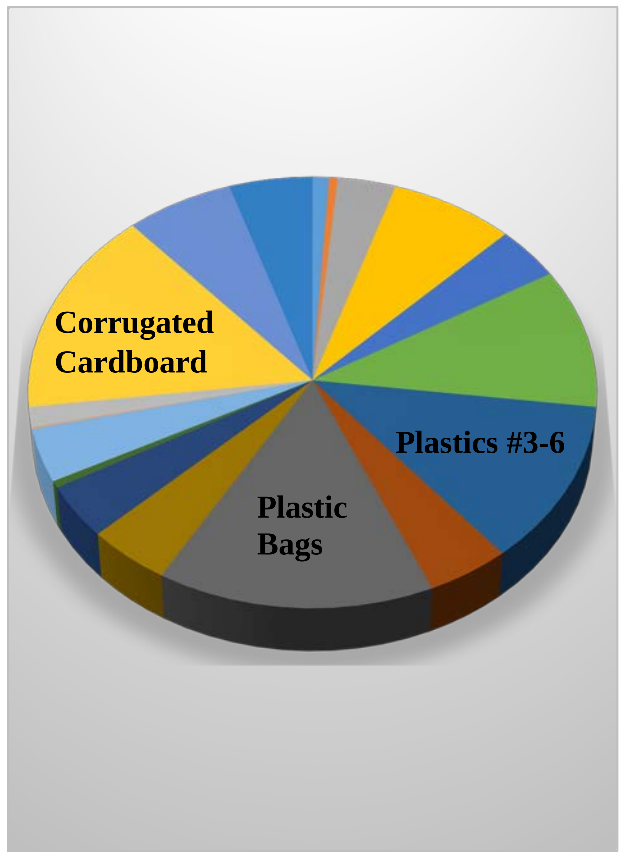



Figure 2: Pie chart representing the percentage of **volume** in each category for Classroom Building North.

| Waste Category | Weight (lbs) | Volume (gal) | % Total Weight | % Total Volume |
|---|---|---|---|---|
| White Paper (clean, dry) | 0.1 | 1 | 0.2 | 1.0 |
| Colored Paper | 0.2 | 0.5 | 0.3 | 0.5 |
| Newspapers, Magazines | 0.2 | 3.5 | 0.3 | 3.5 |
| Non-Recyclable Paper | 7.3 | 7.5 | 12.5 | 7.5 |
| Paperboard/Chipboard | 1.1 | 4 | 1.9 | 4.0 |
| Plastics #1 and #2 | 3.5 | 10.5 | 6.0 | 10.5 |
| Plastics #3-#6 | 2.6 | 12 | 4.5 | 12.0 |
| #7 Plastic and PLA | 1 | 4.5 | 1.7 | 4.5 |
| Plastic Bags/Film | 6.9 | 15 | 11.8 | 15.0 |
| Styrofoam | 0.2 | 4.5 | 0.3 | 4.5 |
| Other Plastics | 1 | 4 | 1.7 | 4.0 |
| Glass | 1.7 | 0.5 | 2.9 | 0.5 |
| Aluminum | 2.7 | 4 | 4.6 | 4.0 |
| Metals (non-aluminum) | 0.1 | 0.1 | 0.2 | 0.1 |
| Drink Boxes (Milk Cartons) | 0.2 | 1.5 | 0.3 | 1.5 |
| Corrugated Cardboard | 6.5 | 15.5 | 11.2 | 15.5 |
| Food Waste/ Organics | 19.6 | 6.5 | 33.6 | 6.5 |
| Batteries | 0 | 0 | 0.0 | 0.0 |
| Trash | 3.4 | 5 | 5.8 | 5.0 |
| Other (very out of place) | 0 | 0 | 0.0 | 0.0 |
| Hazardous Materials | 0 | 0 | 0.0 | 0.0 |
| Total | 58.3 | 100.1 | 100 | 100 |

Table 1: Data Table showing weight and volume distribution for each category in Classroom Building North. Top in weight is yellow, top in volume is blue, and top in both is green.

Family and Graduate Student Housing (FGSH):

A total of 53.2 lbs and 63.5 gal was sorted from several of the apartment buildings that make up FGSH, specifically X2, X3, N-10, N-25, and S-80. The largest percentages of weight were taken up by food waste at 41.0% and trash at 22.4%. These two categories also took up the highest percentage of volume at 10.2% and 15.0% respectively. Non-recyclable paper also took up a large percentage of the volume at 10.2%.

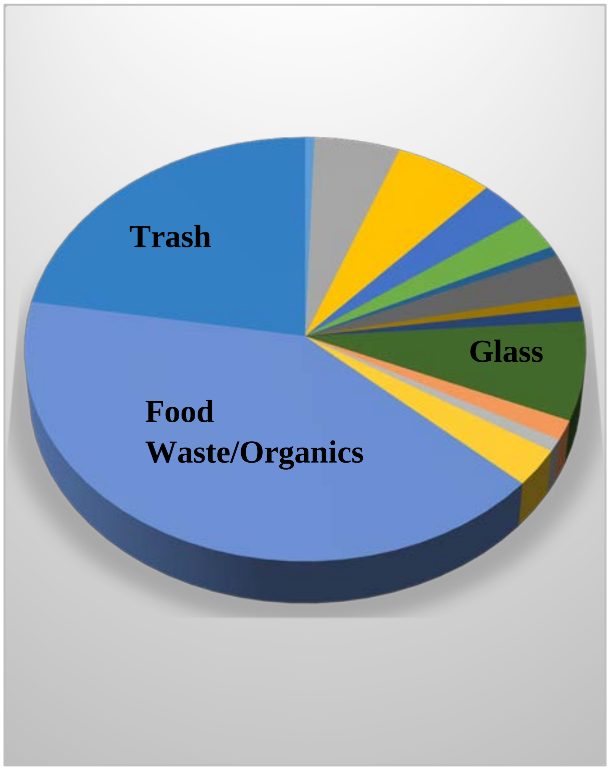



Figure 3: Pie chart representing the percentage of **weight** in each category for FGSH.

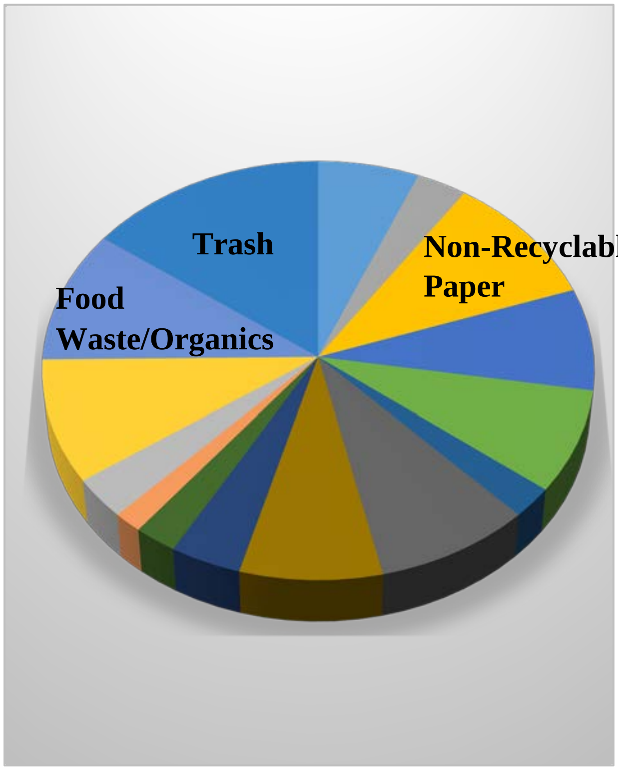



Figure 4: Pie chart representing the percentage of **volume** in each category for FGSH.

| Waste Category | Weight (lbs) | Volume (gal) | % Total Weight | % Total Volume |
|---|---|---|---|---|
| White Paper (clean, dry) | 0.3 | 4 | 0.6 | 6.3 |
| Colored Paper | 0 | 0 | 0.0 | 0.0 |
| Newspapers, Magazines | 2.8 | 2 | 5.3 | 3.2 |
| Non-Recyclable Paper | 3.2 | 6.5 | 6.0 | 10.2 |
| Paperboard/Chipboard | 1.7 | 5 | 3.2 | 7.9 |
| Plastics #1 and #2 | 1.5 | 5 | 2.8 | 7.9 |
| Plastics #3-#6 | 0.4 | 1.5 | 0.8 | 2.4 |
| #7 Plastic and PLA | 0 | 0 | 0.0 | 0.0 |
| Plastic Bags/Film | 1.7 | 5.5 | 3.2 | 8.7 |
| Styrofoam | 0.5 | 5 | 0.9 | 7.9 |
| Other Plastics | 0.6 | 2.5 | 1.1 | 3.9 |
| Glass | 4 | 1.5 | 7.5 | 2.4 |
| Aluminum | 0 | 0 | 0.0 | 0.0 |
| Metals (non-aluminum) | 0.8 | 1 | 1.5 | 1.6 |
| Drink Boxes (Milk Cartons) | 0.5 | 2 | 0.9 | 3.2 |
| Corrugated Cardboard | 1.5 | 6 | 2.8 | 9.5 |
| Food Waste/ Organics | 21.8 | 6.5 | 41.0 | 10.2 |
| Batteries | 0 | 0 | 0.0 | 0.0 |
| Trash | 11.9 | 9.5 | 22.4 | 15.0 |
| Other (very out of place) | 0 | 0 | 0.0 | 0.0 |
| Hazardous Materials | 0 | 0 | 0.0 | 0.0 |
| Total | 53.2 | 63.5 | 100 | 100 |

Table 2: Data Table showing weight and volume distribution for each category in Family and Graduate Student Housing. Top in weight is yellow, top in volume is blue, and top in both is green.

Agricultural Hall (AGH):

A total of 64.3 lbs and 102 gal was sorted from Ag Hall. The largest percentages of weight was taken up by the non-recyclable paper category at 36.2%, which also took up the largest percentage of volume at 25.44%. Clean white paper and food waste also accounted for large percentages of weight, at 17.4% and 15.7% respectively. Plastic bags took up the third most volume accounting for 10.4%.

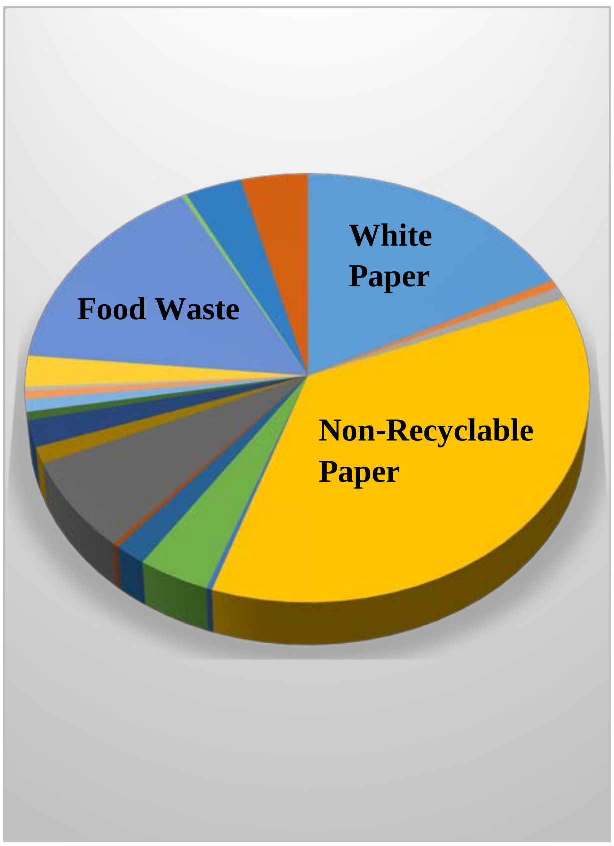



Figure 5: Pie chart representing the percentage of **weight** in each category for Ag Hall.

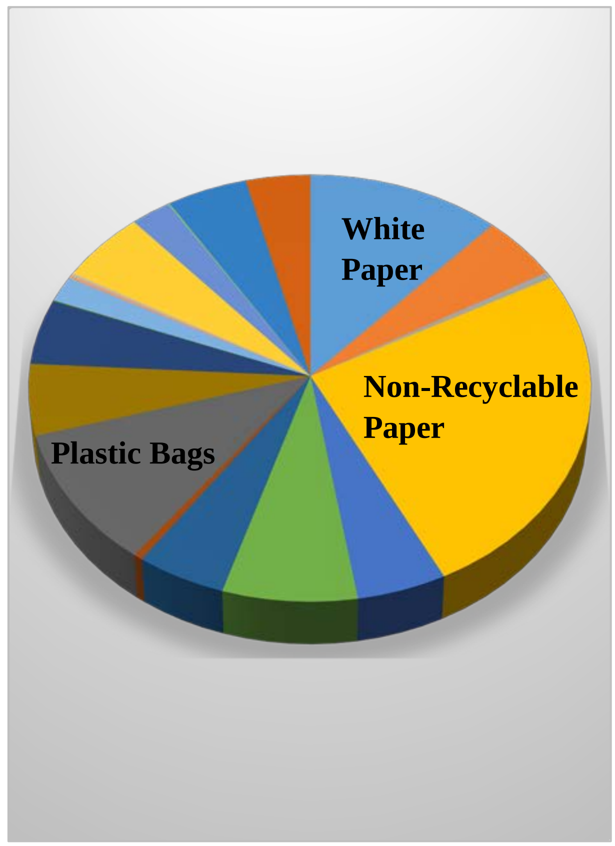



Figure 6: Pie chart representing the percentage of **volume** in each category for Ag Hall.

| Waste Category | Weight (lbs) | Volume (gal) | % Total Weight | % Total Vol |
|---|---|---|---|---|
| White Paper (clean, dry) | 11.2 | 12 | 17.4 | 11.7 |
| Colored Paper | 0.4 | 5 | 0.6 | 4.9 |
| Newspapers, Magazines | 0.6 | 0.5 | 0.9 | 0.5 |
| Non-Recyclable Paper | 23.3 | 26 | 36.2 | 25.4 |
| Paperboard/Chipboard | 0.2 | 5 | 0.3 | 4.9 |
| Plastics #1 and #2 | 2.5 | 7.5 | 3.9 | 7.3 |
| Plastics #3-#6 | 1.1 | 5 | 1.7 | 4.9 |
| #7 Plastic and PLA | 0.2 | 0.5 | 0.3 | 0.5 |
| Plastic Bags/Film | 4.5 | 10.6 | 7.0 | 10.4 |
| Styrofoam | 0.8 | 5.5 | 1.2 | 5.4 |
| Other Plastics | 1.3 | 5 | 2.0 | 4.9 |
| Glass | 0.4 | 0.1 | 0.6 | 0.1 |
| Aluminum | 0.6 | 2 | 0.9 | 2.0 |
| Metals (non-aluminum) | 0.4 | 0.2 | 0.6 | 0.2 |
| Drink Boxes (Milk Cartons) | 0.2 | 0.2 | 0.3 | 0.2 |
| Corrugated Cardboard | 1.5 | 5.5 | 2.3 | 5.4 |
| Food Waste/ Organics | 10.1 | 2.5 | 15.7 | 2.5 |
| Batteries | 0.2 | 0.1 | 0.3 | 0.1 |
| Trash | 2.2 | 5 | 3.4 | 4.9 |
| Other (very out of place) | 2.6 | 4 | 4.0 | 3.9 |
| Hazardous Materials | 0 | 0 | 0.0 | 0.0 |
| Total | 64.3 | 102.2 | 100 | 100 |

Table 3: Data Table showing weight and volume distribution for each category in Agricultural Hall. Top in weight is yellow, top in volume is blue, and top in both is green.

Student Union (SU):

A total of 51.7 lbs and 85.7 gal of waste was sorted from the Student Union. Non-recyclable paper accounted for the most weight and volume in this building, taking up 24.2% of the weight and 17.5% of the volume. Food waste and white paper also took up large percentages of weight, accounting for 23.6% and 13.7% respectively. Styrofoam and plastic bags took up large percentages of volume, accounting for 16.3% and 11.1% respectively.

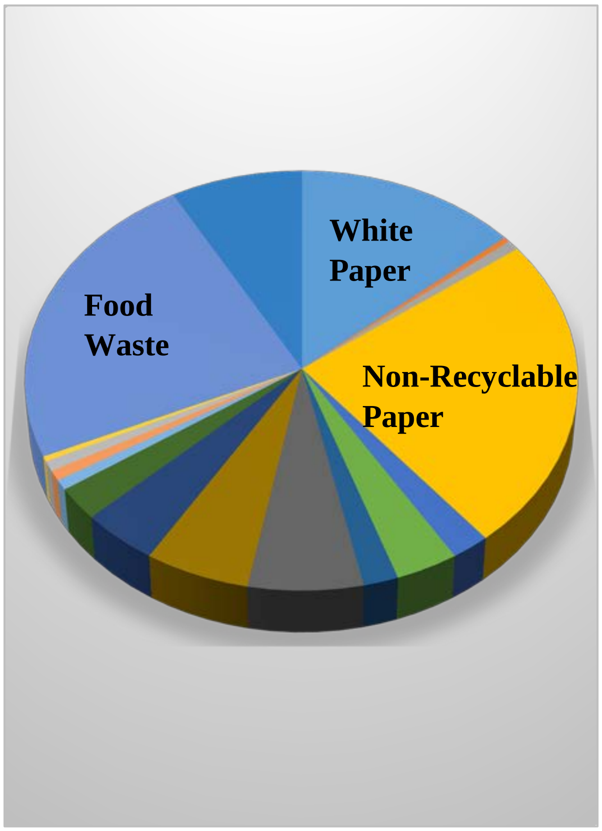



Figure 7: Pie chart representing the percentage of **weight** in each category for the Student Union.

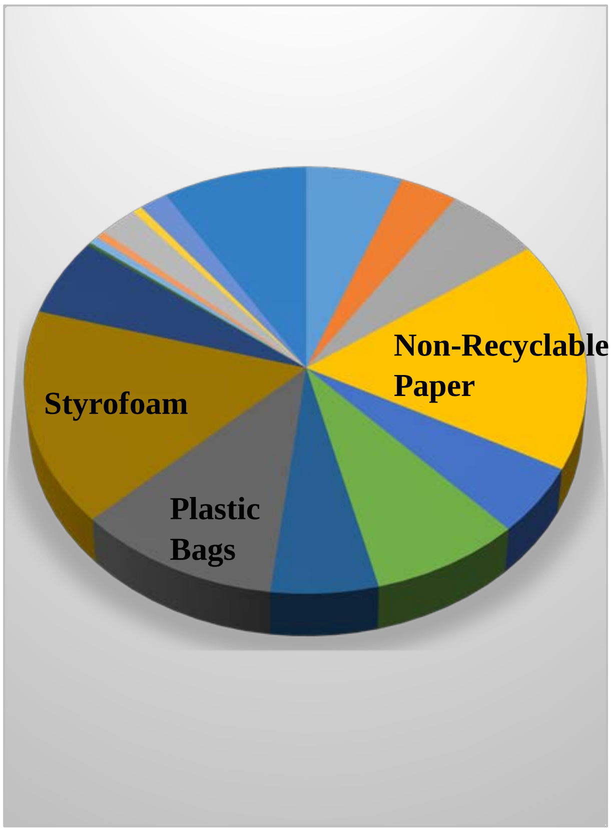



Figure 8: Pie chart representing the percentage of **volume** in each category for the Student Union.

| Waste Category | Weight (lbs) | Volume (gal) | % Total Weight | % Total Vol |
|---|---|---|---|---|
| White Paper (clean, dry) | 7.1 | 5 | 13.7 | 5.8 |
| Colored Paper | 0.2 | 3 | 0.4 | 3.5 |
| Newspapers, Magazines | 0.4 | 5 | 0.8 | 5.8 |
| Non-Recyclable Paper | 12.5 | 15 | 24.2 | 17.5 |
| Paperboard/Chipboard | 1.1 | 4.5 | 2.1 | 5.3 |
| Plastics #1 and #2 | 1.8 | 7 | 3.5 | 8.2 |
| Plastics #3-#6 | 1 | 5 | 1.9 | 5.8 |
| #7 Plastic and PLA | 0 | 0 | 0.0 | 0.0 |
| Plastic Bags/Film | 3.3 | 9.5 | 6.4 | 11.1 |
| Styrofoam | 3 | 14 | 5.8 | 16.3 |
| Other Plastics | 2.2 | 5 | 4.3 | 5.8 |
| Glass | 1.3 | 0.2 | 2.5 | 0.2 |
| Aluminum | 0.4 | 0.5 | 0.8 | 0.6 |
| Metals (non-aluminum) | 0.4 | 0.5 | 0.8 | 0.6 |
| Drink Boxes (Milk Cartons) | 0.4 | 2 | 0.8 | 2.3 |
| Corrugated Cardboard | 0.2 | 0.5 | 0.4 | 0.6 |
| Food Waste/ Organics | 12.2 | 1.5 | 23.6 | 1.8 |
| Batteries | 0 | 0 | 0.0 | 0.0 |
| Trash | 4.2 | 7.5 | 8.1 | 8.8 |
| Other (very out of place) | 0 | 0 | 0.0 | 0.0 |
| Hazardous Materials | 0 | 0 | 0.0 | 0.0 |
| Total | 51.7 | 85.7 | 100 | 100 |

Table 4: Data Table showing weight and volume distribution for each category in the Student Union. Top in weight is yellow, top in volume is blue, and top in both is green.

Henry Bellmon Research Center (HBRC):

A total of 69.8 lbs and 93.8 gal of waste was sorted from HBRC. The food waste and “other” categories were two of the highest in weight, accounting for 28.4% and 14.3% respectively. Styrofoam and Plastics #3-6 were two of the highest in volume, accounting for 11.7% and 11.2% respectively. Trash took up significant percentages of both, accounting for 21.4% of the weight and 12.8% of the volume.


Figure 9: Pie chart representing the percentage of **weight** in each category for HBRC.

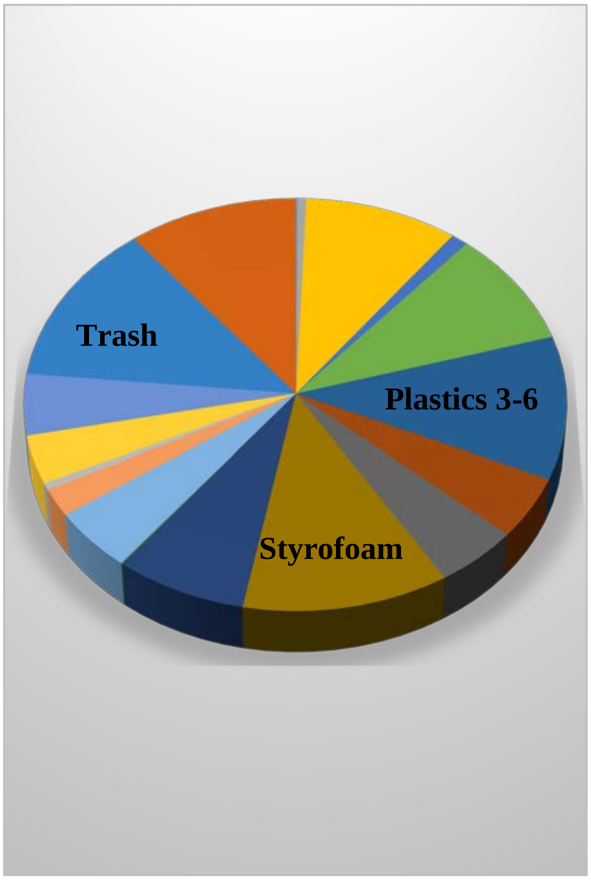



Figure 10: Pie chart representing the percentage of **volume** in each category for HBRC.

| Waste Category | Weight (lbs) | Volume (gal) | % Total Weight | % Total Vol |
|---|---|---|---|---|
| White Paper (clean, dry) | 0.4 | 0.1 | 0.6 | 0.1 |
| Colored Paper | 0 | 0 | 0.0 | 0.0 |
| Newspapers, Magazines | 0.3 | 0.5 | 0.4 | 0.5 |
| Non-Recyclable Paper | 6.6 | 9 | 9.5 | 9.6 |
| Paperboard/Chipboard | 0.4 | 1 | 0.6 | 1.1 |
| Plastics #1 and #2 | 3.6 | 8.6 | 5.2 | 9.2 |
| Plastics #3-#6 | 2.1 | 10.5 | 3.0 | 11.2 |
| #7 Plastic and PLA | 1.1 | 4.5 | 1.6 | 4.8 |
| Plastic Bags/Film | 2.4 | 4.5 | 3.4 | 4.8 |
| Styrofoam | 1.3 | 11 | 1.9 | 11.7 |
| Other Plastics | 2.1 | 7 | 3.0 | 7.5 |
| Glass | 0.6 | 0.1 | 0.9 | 0.1 |
| Aluminum | 1.1 | 4.5 | 1.6 | 4.8 |
| Metals (non-aluminum) | 2.2 | 2 | 3.2 | 2.1 |
| Drink Boxes (Milk Cartons) | 0.3 | 0.5 | 0.4 | 0.5 |
| Corrugated Cardboard | 0.6 | 3.5 | 0.9 | 3.7 |
| Food Waste/ Organics | 19.8 | 4.5 | 28.4 | 4.8 |
| Batteries | 0 | 0 | 0.0 | 0.0 |
| Trash | 14.9 | 12 | 21.4 | 12.8 |
| Other (very out of place) | 10 | 10 | 14.3 | 10.7 |
| Hazardous Materials | 0 | 0 | 0.0 | 0.0 |
| Total | 69.8 | 93.8 | 100 | 100 |

Table 5: Data Table showing weight and volume distribution for each category in the Henry Bellmon Research Center. Top in weight is yellow, top in volume is blue, and top in both is green.

<u>Kamm-Peterson-Friend Residence Halls (KPF):</u>

A total of 47.7 lbs and 80.4 gal of waste was sorted from KPF. Non-recyclable paper accounted for the highest percentage of both sections, taking up 18.9% of the weight and 12.4% of the volume. Food waste and glass took up high percentages of weight, accounting for 17.4% and 12.0% respectively. Plastic bags/film and plastics #1 and 2 took up high percentages of volume, accounting for 12.4% and 10.6% respectively.

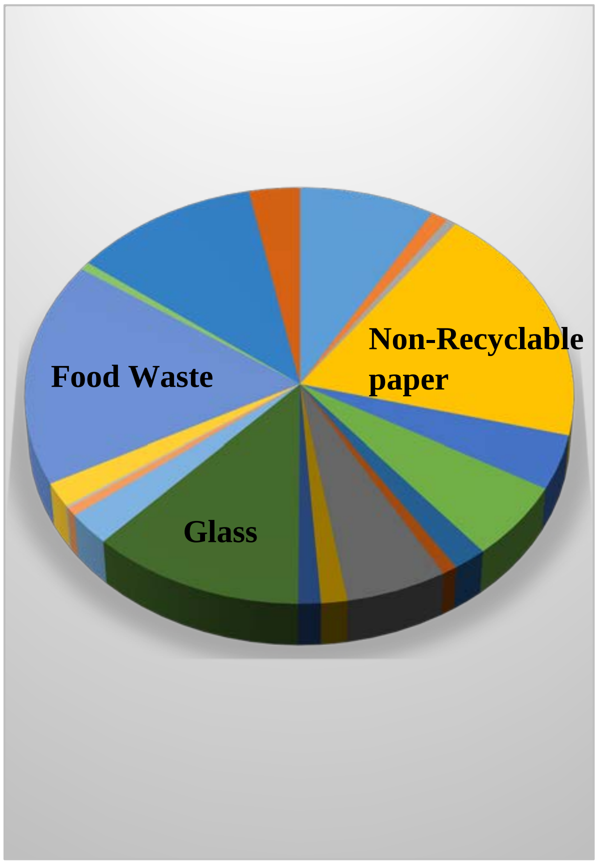



Figure 11: Pie chart representing the percentage of **weight** in each category for KPF.

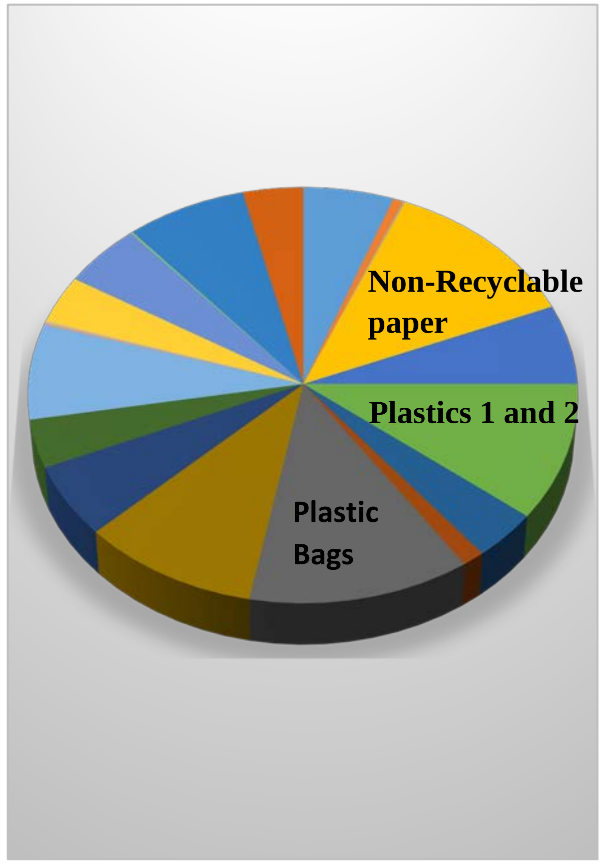



Figure 12: Pie chart representing the percentage of **volume** in each category for KPF.

| Waste Category | Weight (lbs) | Volume (gal) | % Total Weight | % Total Vol |
|---|---|---|---|---|
| White Paper (clean, dry) | 4 | 4.5 | 8.4 | 5.6 |
| Colored Paper | 0.5 | 0.5 | 1.0 | 0.6 |
| Newspapers, Magazines | 0.3 | 0.1 | 0.6 | 0.1 |
| Non-Recyclable Paper | 9 | 10 | 18.9 | 12.4 |
| Paperboard/Chipboard | 2 | 5 | 4.2 | 6.2 |
| Plastics #1 and #2 | 2.8 | 8.5 | 5.9 | 10.6 |
| Plastics #3-#6 | 0.9 | 3 | 1.9 | 3.7 |
| #7 Plastic and PLA | 0.4 | 1 | 0.8 | 1.2 |
| Plastic Bags/Film | 2.7 | 10 | 5.7 | 12.4 |
| Styrofoam | 0.7 | 8 | 1.5 | 10.0 |
| Other Plastics | 0.6 | 4.5 | 1.3 | 5.6 |
| Glass | 5.7 | 3 | 11.9 | 3.7 |
| Aluminum | 1.2 | 6 | 2.5 | 7.5 |
| Metals (non-aluminum) | 0.3 | 0.1 | 0.6 | 0.1 |
| Drink Boxes (Milk Cartons) | 0.1 | 0.1 | 0.2 | 0.1 |
| Corrugated Cardboard | 0.9 | 3 | 1.9 | 3.7 |
| Food Waste/ Organics | 8.3 | 4 | 17.4 | 5.0 |
| Batteries | 0.3 | 0.1 | 0.6 | 0.1 |
| Trash | 5.5 | 6 | 11.5 | 7.5 |
| Other (very out of place) | 1.5 | 3 | 3.1 | 3.7 |
| Hazardous Materials | 0 | 0 | 0.0 | 0.0 |
| Total | 47.7 | 80.4 | 100 | 100 |

Table 6: Data Table showing weight and volume distribution for each category in the Kamm-Peterson-Friend Residence Halls. Top in weight is yellow, top in volume is blue, and top in both is green.

All Six Buildings Together:

A total of 345 lbs and 522 gal of waste was sorted from the OSU-Stillwater campus. Food waste constituted the highest amount of weight, accounting for 26.6%. Non-recyclable paper took up large percentages in both sections, accounting for 17.9% of the weight and 14.2% of the volume. Plastic bags and Styrofoam both took up large percentages of volume, accounting for 10.6% and 9.2% respectively. These four categories were our highest concern when coming up with recommendations.


Figure 13: Pie chart representing the percentage of **weight** in each category for all buildings together.

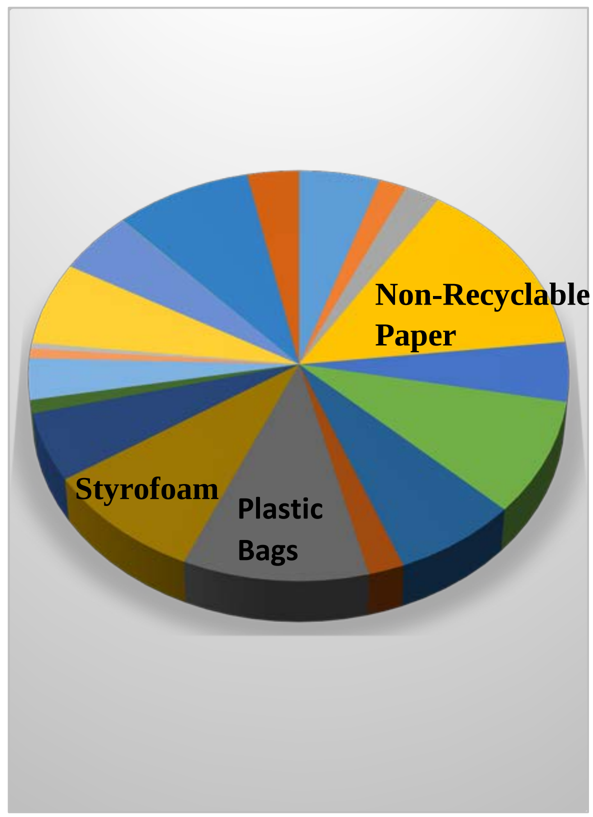



Figure 14: Pie chart representing the percentage of **volume** in each category for all buildings together.

| Waste Category | Weight (lbs) | Volume (gal) | % Total Weight | % Total Vol |
|---|---|---|---|---|
| White Paper (clean, dry) | 23.1 | 26.6 | 6.7 | 5.1 |
| Colored Paper | 1.3 | 9 | 0.4 | 1.7 |
| Newspapers, Magazines | 4.6 | 11.6 | 1.3 | 2.2 |
| Non-Recyclable Paper | 61.9 | 74 | 17.9 | 14.2 |
| Paperboard/Chipboard | 6.5 | 24.5 | 1.9 | 4.7 |
| Plastics #1 and #2 | 15.7 | 47.1 | 4.6 | 9.0 |
| Plastics #3-#6 | 8.1 | 37 | 2.3 | 7.1 |
| #7 Plastic and PLA | 2.7 | 10.5 | 0.8 | 2.0 |
| Plastic Bags/Film | 21.5 | 55.1 | 6.2 | 10.6 |
| Styrofoam | 6.5 | 48 | 1.9 | 9.2 |
| Other Plastics | 7.8 | 28 | 2.3 | 5.4 |
| Glass | 13.7 | 5.4 | 4.0 | 1.0 |
| Aluminum | 6 | 17 | 1.7 | 3.3 |
| Metals (non-aluminum) | 4.2 | 3.9 | 1.2 | 0.7 |
| Drink Boxes (Milk Cartons) | 1.7 | 2.3 | 0.5 | 0.4 |
| Corrugated Cardboard | 11.2 | 34 | 3.2 | 6.5 |
| Food Waste/ Organics | 91.8 | 25.5 | 26.6 | 4.9 |
| Batteries | 0.5 | 0.2 | 0.1 | 0.0 |
| Trash | 42.1 | 45 | 12.2 | 8.6 |
| Other (very out of place) | 14.1 | 17 | 4.1 | 3.3 |
| Hazardous Materials | 0 | 0 | 0.0 | 0.0 |
| Total | 345 | 521.7 | 100 | 100 |

Table 6: Data Table showing weight and volume distribution for each category in all six buildings together. Top in weight is yellow, top in volume is blue, and top in both is green.

## Discussion and Recommendations

After the 2013 Waste Audit, the author found that the most significant categories in weight included food waste and plastics 1 & 2. Thus, her recommendations focused on food waste composting and working harder towards removing recyclables from the waste stream. We found less recyclables like plastics 1 & 2 in the waste stream, however food waste continues to be a significant category. Unique to this study was the finding of non-recyclable paper being significant as well as plastic bags and Styrofoam due to the additional recording of volume measurements. These specific categories directly impacted our recommendations, other recommendations were made based on our supplemental research.

One of the goals of the OSU Sustainability Department is to become a zero waste campus at some point in the future (fm.okstate.edu). We've compared the university's waste production and found a decrease from 3727 tons to 3650 tons since 2013. What is interesting is that there was a 17% drop in waste production from 2013 to 2014 and waste production has been rising since then. It would make sense to correlate that rise with increasing student enrollment, but according to OSU's website, total student enrollment at Stillwater's campus has only risen by a few hundred students over the last four years (irim.okstate.edu). Therefore we must come to the conclusion that improvements must be made and these recommendations must be taken seriously.

Waste Audit Recommendations:

- Plastic bag recycling
  - Plastic bags cannot currently be recycled on campus as they cause the baler to jam, so in order to recycle them they would need to be shipped elsewhere. In

some residence halls there are bins available for students to place their bags but it is up to students to deliver those bags to locations that do recycle them. It would be worthwhile to expand this program by adding more of these bins around campus, specifically all residence halls and convenience stores, and have a student organization officially take care of transporting them.

- Further implementation of reusable bags and cups
  - This will further help reduce plastic bag waste as well as Styrofoam waste, as most of the Styrofoam came from cups. A way to incentivize students to reuse more is by providing discounts on their purchases for using these bags and cups as well as charging extra for using plastic bags or Styrofoam cups.
- Better marketing for white paper recycling
  - Much of the non-recyclable paper was in fact white paper that was thrown out and soiled by food or coffee grounds in the trash. Ways to minimize this waste would be to increase convenience and awareness. Examples would be to have white paper recycling bins next to all trash cans and to have flyers or signs in as many offices and labs as possible reminding faculty to recycle their paper.
- Electric hand dryers
  - Another large portion of the non-recyclable paper was paper towels from bathrooms. Ways to limit this is by installing electric hand dryers. Some buildings like the Colvin already have them and it could help reduce this category of waste if they were put into other buildings as well.
- Actively seek a food waste composter

    - At this point it is not feasible for OSU to implement a food waste composting program, however they should not just wait someone to come along and do it for them. Food waste accounts for the largest amount of weight found in the waste stream and if any large effort is to be made to reduce waste production this must be addressed. It would be most beneficial for the university to actively seek out potential entrepreneurs to implement a composting facility in the region, or to discuss a partnered venture with the City of Stillwater.

<u>Research Recommendations:</u>

- Make "OSU Recycles" single stream
    - We've learned from places like Pepperdine that convenience is key when it comes to recycling, and OSU is already doing some single stream recycling with "Res Life Recycles." Taking out the confusion of sorting things into the right bin could help encourage students to recycle more.
- Modify bin appearance, location, and amount
    - The more recycling bins there are and the closer they are to trash cans, the easier it is for students and faculty to use them. Also, bins across campus in various locations don't all look the same, which can be confusing. Uniform appearance for specific streams would help that. And with appearance, having a large, simple picture on the bin to identify it is easier to interpret than posters and signs full of words.
- Perform a cost audit

    - The Recycling Department currently does not know how much exactly they are spending or gaining with recycling. Performing an audit to figure this out will let them know how much they might be able to spend on improving the program.
- Regular waste auditing
    - Performing a waste audit like this every few years will help keep the university up to date on how what their waste stream is composed of. No one strategy will take a university to zero waste, so studies like this will help OSU adapt and address problems bit by bit.

**References**

[1] "Advantages and Disadvantages of Recycling." *Conserve Energy Future*. N.p., 16 Jan. 2017. Web. 15 Mar. 2017.

[2] Bailey, Kate. "Zero Waste Creates Jobs." *Ecocycle.org mobile*. Eco-cycle, Inc, n.d. Web. 5 Apr. 2017.

[3] "Enrollment Projections." *OSU Institutional Research and Information Management.* Oklahoma State University. Web. 15 April 2017.

[4] "Frequently Asked Questions." *Frequently Asked Questions | Pepperdine University | Seaver College*. N.p., n.d. Web. 09 Mar. 2017.

[5] "Municipal Solid Waste." *EPA*. Environmental Protection Agency, n.d. Web. 20 Apr. 2017.

[6] "OSU Recycles-Mission, Vision, Goals, and Objectives." *OSU Facilities Management*. Oklahoma State University, 11 Sept. 2013. Web. 15 Apr. 2017.

[7] "The past, present, and future of solid waste disposal." *Sustaining Our World*. N.p., 27 Feb. 2017. Web. 29 Apr. 2017.

[8] Payne, Colin. "Breaking Down America's D on Infrastructure." *Breaking Down America's D on Infrastructure > ENGINEERING.com*. Engineering.com, Inc, 31 Mar. 2017. Web. 5 Apr. 2017.

[9] Piccirilli Dorsey, Inc. "Fact Sheet: Landfill Methane | White Papers | EESI". *Eesi.org*. N.p., 2017. Web. 15 Mar. 2017.

[10]"Plastics." *How Plastics Are Made*. American Chemistry Council, Inc, 2015. Web. 29 Apr. 2017.

[11] "Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy." *EPA*. Environmental Protection Agency, 12 Apr. 2017. Web. 20 Apr. 2017.

[12] Thompson, Derek. "2.6 Trillion Pounds of Garbage: Where Does the World's Trash Go?" *The Atlantic*. Atlantic Media Company, 07 June 2012. Web. 15 Mar. 2017.

[13] "University of Oklahoma - Most Widespread." *Sustainability*. N.p., n.d. Web. 09 Mar. 2017.

[14] Kandula, Bhuvana. “Oklahoma State University Waste Audit Report Spring 2013.” Department of Civil and Environmental Engineering. Oklahoma State University. Mar. 2017.

[15] "The Waste Stream: Garbage through the ages." *The Waste Stream - Page 3*. N.p., n.d. Web. 15 Mar. 2017.

**<u>Appendix A—Categories</u>** (Every Category must be relatively clean and dry to be recyclable)

- Copied directly from 2013 report by Bhuvana Kandula.

1. **White Paper:** Most valuable version of paper which can be recycled.
2. **Colored Paper:** This category is determined by tearing to determine base color.
3. **Newspapers, Magazines, and Journals**
4. **Non-Recyclable Paper:** Paper towels, napkins, tissues, food wrappers, wet or soiled paper
5. **Paperboard or Chipboard:** Ex- Cereal boxes
6. **#1 and #2:**

   #1 - PET or PETE (Polyethylene Terephtalate): Usually green or clear, this type of plastic is shiny and rigid and generally used for soft drink bottles, peanut butter containers, water and beer bottles, salad dressings, oil containers, and microwavable food trays.

   #2 - HDPE (High Density Polyethylene): These plastics have milky or solid colors and are rigid containers; they are used in making detergent bottles, pens, and shampoo bottles.

7. **#3-#6 Plastic Containers:**

   #3: PVC (Polyvinyl Chloride): This plastic is semi-rigid, used as dashboards, clear food packing, cables etc.

   #4: LDPE (Low Density Polyethylene): It is a flexible plastic, used in squeezable bottles, tote bags etc.

   #5.PP (Polypropylene): This plastic is semi-rigid, it is generally solid white or colored, it is used in yogurt containers, ketchup bottles etc.

   #6.Polystyrene: This plastic is brittle and glossy, used in medicine bottles, CD cases etc.

8. **#7 Plastic Containers and PLA (corn starch plastic):**

   PLA plastics are made from corn and cane sugar. It is an easily moldable plastic, giving it the ability to protect items during shipping. Examples of PLA plastics are plastic wrapping around items you buy at the store, such as fruits.

9. **Plastic Bags/ Films**

10. **Styrofoam**

11. **Other Plastic Containers and Plastic Container Lids:** Things like restaurant plastic cups that do not fit into other categories.

12. **Glass**

13. **Aluminum:** Soda Cans and aluminum foil

14. **Metals (Non- Aluminum):** Steel or tin cans which have a flat bottom and other metals like brass, and copper.

15. **Drink Boxes:** Ex - Milk Cartons

16. **Corrugated Cardboard:** Cardboard with waffle like construction that makes up the walls the cardboard.

17. **Food Waste**

18. **Household Batteries:** Rechargeable and regular.

19. **Trash**

20. **Other**

21. **Hazardous Waste:** Examples are cleaning fluids, pesticides, and by products of manufacturing processes.

**<u>Appendix B—Waste Audit Pictures</u>**

Volunteers sorting the trash


Measuring and recording weight and volume