One Man's Trash can be Everyone's Burden: A Case Study Analysis of Rutherford County's Waste Status

by
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A thesis presented to the Honors College of Middle Tennessee State University in partial fulfillment of the requirements for graduation from the University Honors College

Fall 2018

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Acknowledgements

I want to take a moment to recognize my amazing family who have always supported me. Especially my mom, Karen Horner, who spent countless hours reading and editing and consoling me through this entire thesis project. None of this would have been completed without her support. Also, Bronwyn Graves's help with her editing and great advice throughout the whole process.

I would like to acknowledge Dr. Anthon Eff, my supportive and patient project advisor for this thesis. He was always supportive of my ideas and knew how to keep my project on-track and on-time. I truly thank you for all of your help.

I must thank Dr. Kathy Mathis. Though listed as a second reader on this thesis, I owe her credit for where I am today. When I first met with her and discussed adding the Environmental Sustainability degree to asking for her help in providing sources of information for this thesis, she has encouraged me to always keep asking questions and know that there is not one answer to any question. Thank you for all of your guidance and allowing me to continually ask questions both in and out of class.

Thank you to the many specialists in this field that shared their knowledge with me, and I included in the following paper. I truly appreciate all of their help and generosity to share their information with me.

Abstract

Today, waste disposal and generation are notorious concerns for the world. This concern is being worsened by the declining recycling market. As a civilized community, improper waste disposal can be dangerous to the health of the citizens, but people do not want to know how waste is disposed after they place it in the trash bin. Rutherford County in Tennessee has a unique waste situation. Two landfills are located near its center providing the entire County with free waste disposal since 1995. Within the next ten years, both landfills will have closed, and Rutherford County residents will begin to pay for waste disposal. This paper analyzes the effect of waste disposal on Rutherford County's triple bottom line (environmental, social, and economic). Going forward, Rutherford County needs to build an Integrated Solid Waste Plan and set strategic goals that gain the community's approval and limit environmental impact.

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Introduction:

Waste is as much a human invention as the car or the cellphone. In nature there is no waste. No other living organism throws anything away, because in the natural world, there is no "away." Like the satellite space stations, everything recycles back into the system. Even the laws of physics say nothing can be created or destroyed. Waste, trash, rubbish—we have created a new category for items after we are done using them.

Being a human invention, waste has a large effect on people's quality of life, and thus waste management is as important as air, food, water, and shelter to our survival. Certain wastes can be hazardous or cause diseases ("The Importance …"). Knowing this, the Environmental Protection Agency (EPA) stepped in during the 1980s, realizing as urban centers continued to grow there needed to be mandated waste disposal laws to protect public health and safety. Unfortunately, a landfill is one of the most basic and common end-of-life scenarios for "waste." In its essence it is a hole in the ground that we have filled with items we dub trash. A sanitary landfill, defined by Waste 360, is a highly complex biological and chemical processing and storage facility (O'Leary). Landfills have evolved and use more technology today, attempting to be more environmentally friendly and to keep technological pace with modern society.

This paper is a case study on Rutherford County's present waste situation. Currently Rutherford County's waste is picked up for free and delivered to Middle Point landfill or Rutherford County landfill. Middle Point landfill began in 1988 designated as a Class I disposal facility. A facility that can take any non-hazardous municipal solid wastes such as household wastes, approved special wastes, and commercial wastes. The

Rutherford County landfill is permitted as a Class III and IV disposal facility. It can only take landscaping, land clearing, farming wastes, construction or demolition wastes, shredded tires, and waste with any similar characteristics. The Solid Waste division of Rutherford County is responsible for management and ongoing maintenance of the former Rutherford County landfill in the same location. Recently the landfill closed to all construction waste and now accepts only landscape wastes and a limited number of tires per household. These two landfills are on adjacent lots with Middle Point having 808 acres but only using 207 of these acres for disposal (Republic Services). Rutherford County has about 288 acres for its landfill. Within the next 8-10 years the Middle point landfill will close permanently leaving Rutherford and 27 other counties without a Class I landfill. The Rutherford County landfill closed in 2018.

This paper analyzes Rutherford County's waste situation, most likely future outcome, and the environmental, social, and economic impacts thereof. Specifically discussing the different technologies that are in the public and political foreground is important to Rutherford County's future. The global impact of waste and recyclables and how it affects Rutherford County must be considered. All these alternatives will be compared to the triple bottom line and discussed if reasonable for Rutherford County to pursue. This paper is about gathering information rather than providing an answer.

Local Public Opinion:

To estimate public opinion, media articles published for the local area including the Murfreesboro Post and Daily News Journal and the frequency of public complaints submitted to the Solid Waste division were considered. From these articles and

committee decisions, it seems that the public sees Middle Point Landfill and Republic Services who manages the landfill as untrustworthy or misleading. The Rutherford County landfill is often not discussed. This is because the adjacent properties are viewed as one giant landfill to the eyes of the residents. The immediate neighbors of the landfill have made several formal and informal complaints about bad odors continuously detected from the landfill. Despite these complaints, the neighbors have not felt any relief from Middle Point's corrective efforts. There is mistrust of the validity of the efforts Middle Point claims. Many levy accusations that Middle Point works twenty fours a day to avoid the requirement to daily cover the trash—which prevents smells and bird accumulation. However, Republic Services' website says it has strict operation hours only during the working day on Monday thru Friday, shortened hours on Saturday, and off on Sunday.

Global Waste Situation:

The total waste projection increase is estimated around 58% for all the regions by 2025 (Hoornweg). Part of this increase is probably due to the increasing population and amount of people moving towards urban areas and out of rural. The waste generation composition is the percentages of each sector of waste in a specific geographic area. The composition is influenced by culture norms, economic development, climate, geographic location, and energy sources (Hoornweg). The composition should have a direct effect on how the waste is disposed. Typically, lower income countries have a higher organic waste than the higher income, more urbanized countries and the consumption of inorganics increases with urbanization (Hoornweg). According to the World Bank Group, the United States is a high-income level country with a waste mix of 25% organics, 34%

paper, 12% plastic, 5% glass, 8% metal, and 16% other (Hoornweg). When comparing this with another high-income level country such as New Zealand, the range of waste composition in high-income countries alone can be seen. New Zealand's waste mix is 56% organics, 21% paper, 8% plastic, 3% glass, 7% metal, and 5% other (Hoornweg). These numbers explain why New Zealand has more composting and recycling than the United States. Their waste mix is made up of more organic waste and plastic recycling.

"Waste is mainly a by-product of consumer-based lifestyles that drive much of the world's economies." (Hoornweg). The quantity generated per person is increasing and will only continue to rise as population increases. Waste generation has been found to be a larger problem than waste disposal (Hockett). Disposing of the waste has become a significant problem since the amount of waste generated has increased. It seems that reducing waste generation could be a solution to the waste disposal problems as well. Urbanization itself has a variable effect on waste generation, occasionally having an effect but not always (Hockett). Urbanization forces more people in a consolidated area, which requires a more sophisticated collection system. With many retail options in urban settings, the opportunities to overconsume increases. Another possibility is that more people live in the city compared to rural areas linking back to the increase of waste caused by the increase in population unduly showing urbanization to have a positive effect. Overall these studies have conflicting results because of the lack of a universal definition of the types of waste and disposal methods.

National Waste Situation

In the Southeast United States North Carolina, South Carolina, Georgia, Kentucky, and Tennessee all share similar economic and population characteristics. Duke University's study highlights the fact that population growth is correlated with an increase in municipal solid waste generation (Hockett). The only significant variables they found to have an impact on waste generation are landfill tipping fees and amount of retail sales (Hockett). As tipping fees increased, waste generated per capita decreased, but one of the largest uncertainties with this statement is did people reduce their consumption, begin to dump their waste illegally, or burn it themselves.

Solid waste needs to be managed by an Integrated Solid Waste Management Plan. The plan should include sections addressing the municipal policies and initiatives, the character and scale of the host city, data on all waste generation and projections, all proposed options for waste collection through disposal of each identified waste type, evaluate Best Practical Environmental Options, the proposed plan specifying details, specification on monitoring and controls, regulatory support required, financial assessment of the plan including the finance revenue streams, management of non-municipal solid waste problems, plan covering the next 5-10 years with an actionable plan of the next 2-3 years, detailed outline of the program, and the environmental assessment of greenhouse gases emissions or other concerns (Hoornweg). The Integrated Solid Waste Management Plan seems overwhelming with its breadth and information, but this is the best practice that city managers can do to make safe and informed decisions about their solid waste (Hoornweg). Completing an assessment like this will uncover the

most likely outcomes and successfulness of this plan in the future. The framework for this plan is based around stakeholders including anyone involved in creating the program, elements of the technical aspects, and aspects including the regulatory, financial, and environmental realities of the waste management (Hoornweg). A comprehensive plan as suggested will help protect the future society and environment around this waste management plan and ensure people that due diligence was completed before deciding on an action. Landfills need to be managed to prevent the spread of infectious vectors and increase public health. Poor waste management is just as dangerous to human health as water pollution and air pollution.

Local Waste Situation

In Tennessee, the solid waste is successfully collected and disposed for human health by the standards set by the Environmental Protection Agency (EPA) and Tennessee Department of Environment and Conservation (TDEC) to ensure that the landfills have preventative vector measures and environmental measurements. Since Rutherford County is beginning to truly urbanize with increases in population and Murfreesboro City's limits growing daily, solid waste is a major issue. Waste generation is expected to increase as more people move into the county (Gershman).

Rutherford County Landfills:

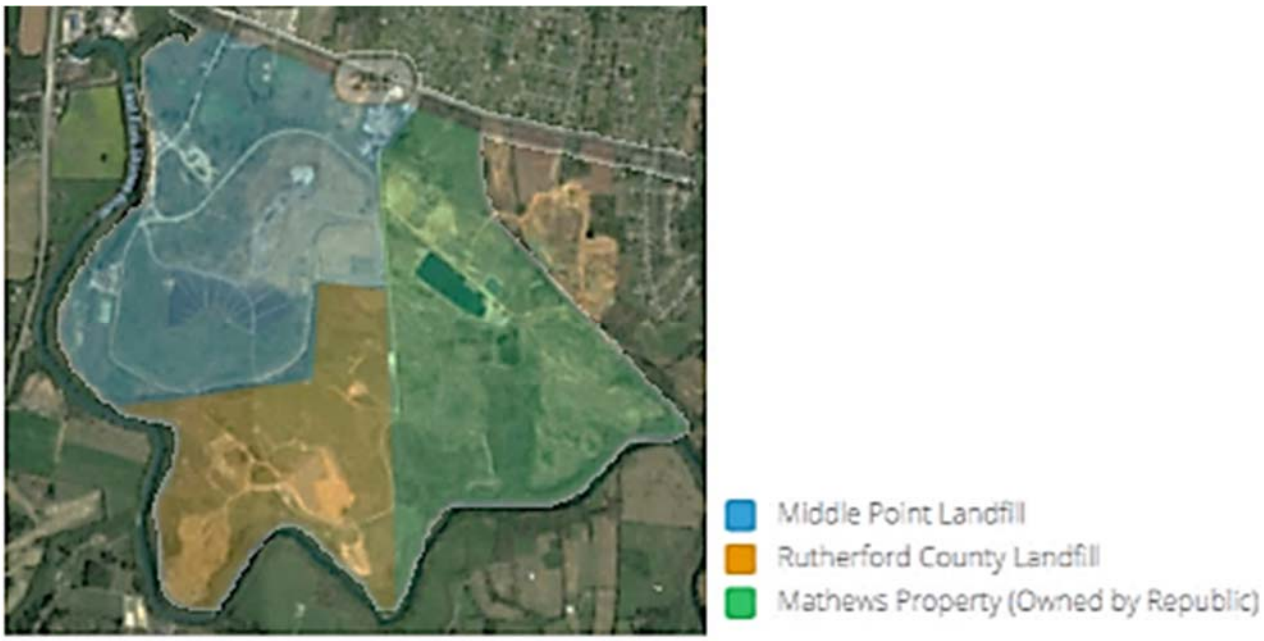

Figure 1: Image of Rutherford County's Two Landfills (Middle Point and the Rutherford County Landfill) overlaid with property lines. Data Source: Republic Services and Google Earth Images

Before the late 1980s there was no regulation on landfills. Waste management was left to the trash owner. A town needed to have a specific piece of property where the residents could place their trash which was known as the County Landfill, but some residents still chose to dump their trash illegally or to burn the trash in their own backyard. The County landfill was tested annually to ensure that a daily cover was being put on correctly, but there were no other requirements for a landfill during this time (Nolen, Smith). This situation led to Rutherford County running an unlined and unmonitored Class I landfill from 1974 until 1994. Class I landfills can gather any household waste and only approved special wastes ("Landfill Permit").

Table 1: Tennessee Department of Environment and Conservation Landfill Class Definitions

Type	Description
Class I Disposal Facility	Takes non-hazardous municipal solid wastes such as household waste, approved special wastes, and commercial wastes
Class II Disposal Facility	Takes non-hazardous industrial wastes, commercial wastes, and fill
Class III Disposal Facility	Takes Class IV wastes plus landscaping, land clearing, and farming wastes
Class IV Disposal Facility	Takes construction/ demolition wastes, shredded tires, and waste with similar characteristics

Data Source: "Landfill Permit", Tennessee Department of Environment and Conservation

Today Rutherford County runs a Class III/IV landfill on the same property as its old landfill. A picture of both landfill's sites is displayed in Figure 1. In the past five years, the construction and demolition side of the landfill has shut down due to being at full capacity and only collect tires and yard waste. Rutherford County owns and operates fifteen convenience centers throughout the county. The convenience centers are manned and inspected once a year if not more often. Murfreesboro City owns one convenience center with restricted hours because it does not have enough capacity to serve the current Murfreesboro residents. A map of these locations can be seen in Appendix B. Any household waste from these centers goes to Middle Point while only the yard waste is taken to the Rutherford County landfill or to the Murfreesboro Mulching company.

Technology:

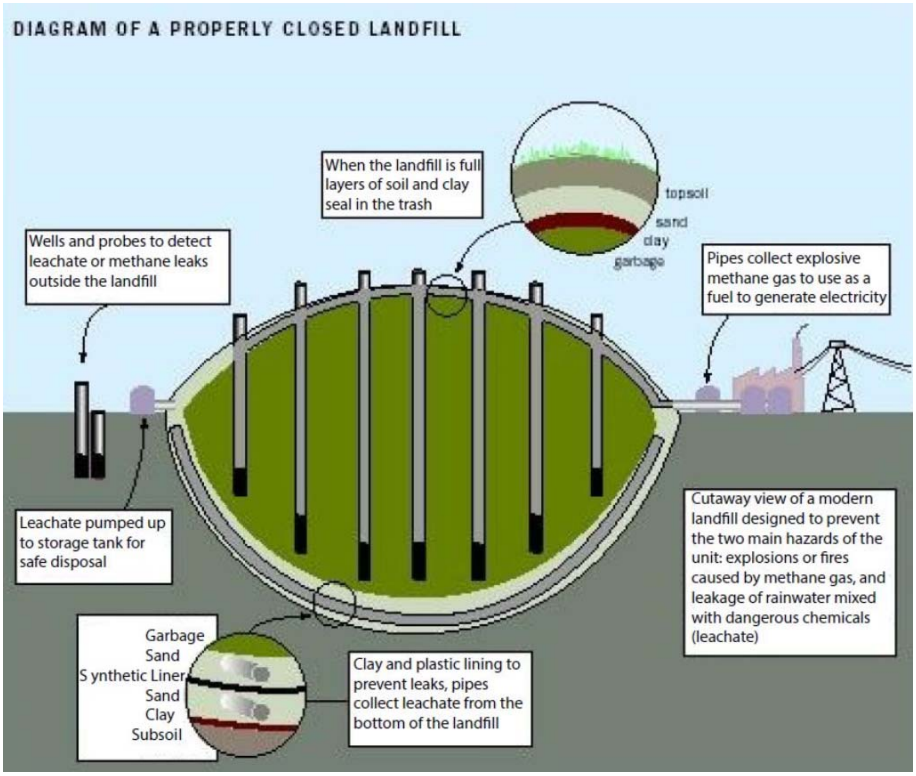

Figure 2: Diagram of a Properly Closed Landfill. Data Source: "Municipal Solid Waste Landfills." United States Environmental Protection Agency. September 13, 2018. Web.

First, let me describe how a modern landfill functions and how this compares to Rutherford County's situation. Modern landfills must be built under a certain design just as building construction has codes to follow. A landfill's structure is in the shape of a giant hole in the ground that becomes a giant circle of trash halfway beneath and halfway above the ground. Picture it as a giant trash bag in the ground. The Environmental Protection Agency (EPA) was the first organized, national agency to set legal regulations on environmental issues. Before the EPA, solid waste was simply dumped into a convenient, literal hole-in-the-ground with only an annual review to ensure that the daily

cover was in place to reduce the smells and vectors. The EPA defines a municipal solid waste landfill as any discrete area of land that receives household waste ("Municipal Solid Waste Landfills”). Before anyone starts digging any land for a landfill, they have to obtain a multitude of permits from the Tennessee Department of Environment and Conservation (TDEC) and show a detailed engineered, master building plan. Six required parts of all modern landfills are location restrictions, composite liners, leachate collection systems, operating practices including compacting and covering waste, groundwater monitoring, and post-closure care requirements ("Municipal Solid Waste Landfills").

The location restrictions are to reduce the likelihood of movement from the primary byproducts of landfills: leachate and landfill gas. Leachate is the water that exudes from all decomposing waste and any water that touches waste is assumed to have been contaminated and treated as leachate. Leachate can carry heavy metals, toxins, or bacteria. Landfill gas is the natural methane gas that is created in landfills from the waste decomposing. Subsurface geologic conditions such as wetlands, faults, or floodplains are more conducive to water drainage ("Municipal Solid Waste Landfills"). Ideally the land underneath a landfill is not conducive to drainage to protect the environment in case there is a leak of one of the byproducts. The soil conditions are taken into consideration when designing the landfill base, collection system, and monitoring type. The best location for landfills is one that has natural drainage patterns away from the landfill working face (O'Leary). Tennessee has a karst geologic environment which means that there are some open cavities in the ground naturally instead of soil which affects sewer systems,

sinkholes, and general construction. This along with topography means that Tennessee landfills need a well-designed drainage system.

Second, the composite liners include at least a three to five-foot thick layer of clay covered in sand, then one or two layers of plastic liners thicker than average also covered in sand (Nolen, Smith). These layers create the bottom of the landfill and are meant to reduce water movement. The bottom clay liner reduces downward water movement and becomes nearly impermeable (O'Leary). Above this is the geomembrane layer which are typically made of high-density polyethylene (HDPE). This plastic is the heaviest duty and can withstand a large amount of pressure. The geomembrane limits water reaching the clay liner (O'Leary). These liners are chosen and engineered for the maximum amount of safety considering the topography and hydrogeology of the area. Landfills are engineered in-place to be the safest location, it is not a one-size-fits-all construction.

Third above the liners, a leachate collection system is put into place. Since water is typically gravity fed having the collection system at the bottom of the landfill ensures that the majority is collected (O'Leary). The drainage layer is designed to move water laterally and stays within one foot above the liners (O'Leary). Leachate collection lines are pipes perforated with holes along the sides to allow the leachate in from all sides, sloping towards a collection point where it can be eventually drained and sent to the local waste water treatment facility (O'Leary). At Middle Point, the leachate is pretreated in a Membrane Biological Reactor before it is sent to Murfreesboro's water treatment facility per their contract (Republic Services). 30.5 million gallons of leachate was pretreated at Middle Point in 2017 (Republic Services). Ironically, the leachate is piped to the waste

water treatment plant only to later return there as part of the sewage sludge. The waste water treatment plant is currently disposing of 100 – 120 tons of solid sludge at the landfill daily. After the leachate collection system is installed, waste can begin to be placed in the landfill.

Fourth, there is a specific order for opening new cells and an engineer approves the cell and ensures it fits within the master building plan (Nolen, Smith). Before placing the first load of waste, the operators place a specific amount of waste over the liner to ensure it is not compromised by the weight of the incoming trucks (O'Leary). The landfill is slowly filled in cell by cell according to the master plan and to ensure that not one part of the cell gets too tall before the others can be opened. It's like stacking books vertically; there is a breaking point where the tower of books begins to lean one way or the other. One places books in a tower beside it before it tips over, and the landfill cells work the same way. There is a specific order to open and fill each cell before starting the next one.

Since Rutherford County's landfill opened in the 1970s it does not have a liner system placed underneath it (Nolen, Smith). Rutherford County government has retroactively installed a leachate collection system and a landfill gas collection system, and they conduct more water testing around the landfill because of this failure (Nolen, Smith). A major problem they face is the fact that they cannot prevent any problems, so instead they react to anything that does go wrong (Nolen, Smith).

Middle Point has its first cell lined with a five-foot thick clay under the old regulations, and the rest of their cells have the five-foot geologic buffer and two-foot of

compacted clay plus a geosynthetic membrane in compliance with today's regulations (Nolen, Smith and Republic Services). The leachate and landfill gas collection systems were always considered and installed as the landfill was being built.

Landfill gas collection (LFG) systems are vertical installations where the other construction pieces go horizontal along the whole surface. The collection systems are installed down within the waste as it is being built up. There are a few different ways to collect the landfill gas. One common way is perforated pipes installed down into the waste. LFG systems are designed with the proper number of wells, spacing, adequate size and depth of well boreholes, and sealing around the screens to decrease leakage (Clark). The first line forms a closed loop to create a natural vacuum that will pull the gas out to the surface for treatment (Clark). At the surface, the goal is to primarily have methane with a limited amount of oxygen because when flaring the gas, all of the gas needs to burn and turn into carbon dioxide. Landfill gas is typically vented, burned, or extracted for fuel (Soto). All three of these require the methane to be extracted out of the waste and brought to the surface.

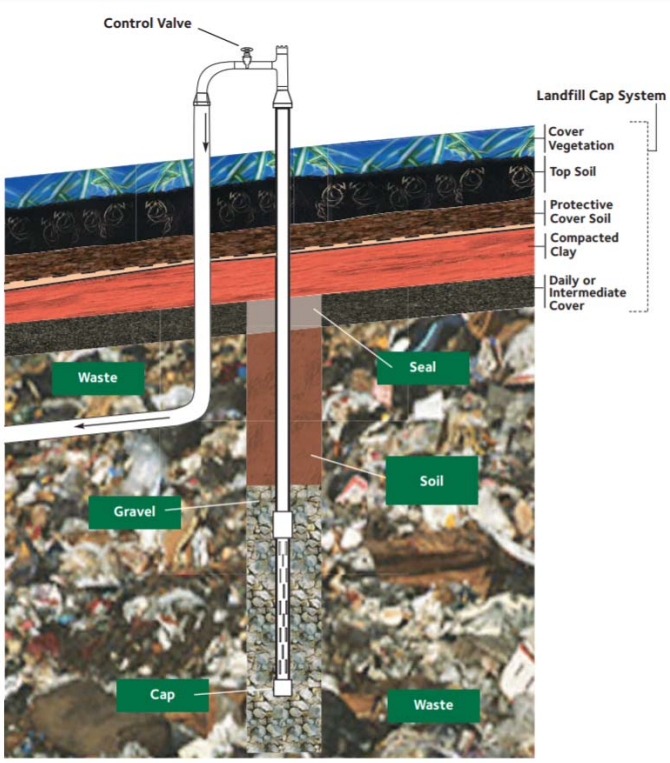

Figure 3: Typical Landfill Gas Extraction. Data Source: "Typical Landfill Gas Extraction Well" Waste Management. Web.

The first step is drilling boreholes down into the waste at least 24 inches in diameter. Since methane is created by the decomposition, the older waste at the bottom of the landfill holds a large portion of the methane (Soto). These boreholes tend to go down to the bottom of the landfill just before the liners. The waste is removed from the boreholes to install the pipes down into them After sending the pipe down, the gravel and other material fills in around the pipe as a casing to protect it from the waste debris ("Typical Landfill Gas Extraction Well"). The pipe itself is perforated with holes and has a cap on the end of it. The piping and hoses are made of high-density polyethylene (HDPE) and polyvinyl chloride (PVC) plastic to withstand the landfill contaminants (Soto). From Figure 3**,** the seal is installed along the daily cover to ensure that the only

gas that comes to the surface is through the pipe and not beside it. Above ground they install a well head where the decision of venting or burning is decided. If the methane concentration is minimal then the gas can vent into the atmosphere if not a burner is placed at the top with an igniter that periodically fires off any methane that is coming out of the pipe (Soto). If there is a large amount of methane, then it can be directed from the wellhead to a cleaner and generator. Landfill gas is often corroded with organics, metals, or even some sediment that gets through the perforations. Before the gas can be used as a fuel it needs to be cleaned and concentrated to become a viable fuel source. At Middle Point landfill, they are so large that the fuel has to be burned rather than vented into the atmosphere, but it is not large enough to use in a generator. Middle Point has 216 gas wells with burners on them at the wellhead. Though they invested in a landfill gas generator the project has become unsustainable as the cost of electricity is cheap and the cost to clean the gas is expensive. It costs them less money to burn it.

The old Rutherford County landfill produces too much methane to vent, so they burn off their landfill gas. It has 44 gas wells that flare to help vent the gas away from the water source. These vents go into the landfill ground and stand about five to six-foot-tall with a solar powered ignitor that constantly ignites any methane coming out (Nolen, Smith).

Plate 1: Oamaru Landfill in New Zealand, depicting the “open face” of the landfill

Every day the open working face of the landfill needs to be closed for the night to prevent odors and reduce vectors in the area. Typically, the face is covered with six inches of dirt. Republic Services uses an alternative daily cover as opposed to a layer of dirt. They stretch out a piece of plastic over the trash while dumping a fine gravel layer on top to hold the plastic down overnight (Nolen, Smith). The following morning, they leave the plastic and place the day’s trash on top (Nolen, Smith). By doing this Republic Services reduces its need of many bulldozers pushing the soil across the open face every night which uses a large amount of fossil fuels and soil that they need to be able to spread. Since their alternative daily cover does not seal entirely, they continue to have odor control problems (Nolen, Smith). To address the odor and dust problems, Republic Services installed a misting/ odor-neutralization system (Republic Services).

Generally, the type of waste that thrown away at a landfill is not recorded. Only special and hazardous waste are required to be recorded by law (Nolen, Smith). When Middle Point accepts special waste, the facility and the disposer need to have Tennessee Department of Environment and Conservation (TDEC) approval. Special waste can be

any hard-to-manage material, a description that involves the volume of material not just the type of material (Nolen, Smith). Before material from the manufacturing processes can be disposed, the material needs to be sent out for T-clip testing which identifies exactly what the material is, what it will react with, and how dangerous it is by itself (Nolen, Smith). Middle Point can accept special industry waste including chemicals, but proper documentation goes along with it (“Landfill Permit”). They currently do not accept hazardous, liquid, untreated medical, or “Bulk Survey for Release” program materials (Republic Services). Though people are not sure exactly what waste is dumped, it is tracked. The original collection location and what truck deposited it is tracked on where they dump their loads inside the landfill. Republic Services does have procedures to ensure that no prohibited waste is dumped in the landfill (Republic Services). Today’s landfills include geo-identification mapping software. As the truck enters the landfill, it is marked with an identifying number. This is recorded along with the location in the landfill trucks dump that specific load.

After the landfill is full, the land needs to be capped to completely seal out any air or water. Capping the landfill is essentially “tying the garbage bag tight.” This final cover is meant to minimize liquid infiltration and soil erosion and needs to have an infiltration layer and an erosion layer ("Requirements …”). Additionally, the land must have a layer of clay to prevent large amounts of water from getting in as the risk of leachate becomes much higher if water can get in from the top but not escape the bottom ("Requirements …”). After the clay comes a layer for erosion control and a layer that will encourage grass growth ("Requirements …”). Now the ground is ready to have shallow rooted

plants planted. The plants over the landfill can stay healthy. Maintained monitoring of the leachate and landfill gas will protect the surrounding area.

Post-closure care must be continued for at least the next thirty to fifty years because many of the monitoring and catchment systems are run on gravity and slope, and ground shifting has a significant effect on the systems' efficiency. Because of this inefficiency, old landfills are quite often used for parks. Any plant can thrive on top of the landfill if the roots will not puncture the top liner. Nature growth on the old landfills will help revive the local area. In New York, the company Field Operations has transformed one of the world's largest landfills, Freshkills, into a major park, three times the size of Central Park (Jacobs). Figure 4 is a model they have in the park's visitor center showing the structure of the park's final cover. Between the barrier protection layer and the soil barrier layer is a drainage layer, impermeable plastic liner, and a gas venting liner (Jacobs).

Figure 4: Closed Landfill Model in Sections. Data Source: *Jacobs, Karrie. "How the world's largest landfill became New York's biggest new park." Curbed New York. September 13, 2016. Web.*

The main goal is to keep the garbage from rising to the surface and manage the landfill gas and leachate that builds up in the waste pile (Jacobs). Republic Services caps its waste with 18 inches of soil or clay, a low-density polyethylene liner, a geocomposite drainage layer, and finally 18 inches of topsoil and vegetation (Republic Services). The result appears like any other natural park. Because of any recurring soil instability, structures are not often built on top of the old landfills. Post-closure care of the landfill will continue at least for the next thirty years, though most are still being monitored today nearly fifty years after closure (“Requirements …”). Though the ground is relatively inert, the people responsible still need to monitor it to protect public and environmental health. One typical problem is the waste shifting as it decomposes leading to the whole

mound needing to be re-shaped every four to five years to increase stability and ensure that the monitoring systems are still in the right place and working (Nolen, Smith).

Economic:

In 1995, when Rutherford County's old Class I landfill shut down, the Rutherford County commissioners signed a contract with the original owners of Middle Point, Browning Ferris Industries (BFI). Per this agreement, Rutherford County forfeited any rights to comment or legislate on Middle Point's business choices or how it is managed in exchange for $1.20 tipping fee on any out-of-county waste that is disposed in Middle Point and free dumping at Middle Point for all Rutherford County citizens (Gershman). The tipping fees account to almost one-million-dollars in revenue to Rutherford County (Nolen, Smith). Currently Middle Point receives waste from 37 counties including Rutherford County, and these counties are depicted in Figure 5 (TDEC Annual Progress Report). Though Middle Point may only have a contract with 27 counties (Republic Services). In 2017, ten additional counties disposed of a portion of their waste in Middle Point.

With this increased popularity, Middle Point has been experiencing severe queue lines estimated at over 400 trucks a day (Nolen, Smith). Rutherford County's trucks make on average 7.8 loads per driver per day (Nolen, Smith). Rutherford County's trucks have been known to sit at the landfill for an hour and a half to two hours waiting to dump their load (Nolen, Smith). The amount of time trucks sit without being productive is a significant cost to Rutherford County (Nolen, Smith). Since trucking fees are a large portion of operation costs according to Rutherford County, where landfill waste is

disposed depends significantly on mileage or relative distance. However, looking at Figure 5 there are several counties that seem to be outliers to this rule. For example, Overton County sends nearly 25,000 tons of waste to Middle Point, but it is 110 miles away (TDEC Annual Progress Report). Where Cannon County sends Middle Point 7,000 tons of waste and is 25 miles away measuring from the center of each county (TDEC Annual Progress Report). There are several of these examples from Madison County to Dickson County. It seems that something else is affecting these tonnages like the contracts that Republic Services has mentioned. For example, Republic Services has recently signed a contract with Metro Nashville to handle their waste, and Davidson County is the largest contributor to Middle Point's annual tonnage. Where the waste is disposed depends on who owns the contract. The company drives the waste to their own landfill either to avoid another company's landfill tipping fee or to gain a double benefit by charging the contract for them collecting and disposing of the waste. This would explain why Rutherford County sends 52,000 tons of waste to West Camden landfill that is owned by Waste Management, a popular waste collection company in the Murfreesboro area based on the trucks seen driving down the streets of Murfreesboro City and the proximity of their Waste Management Transfer Station in Antioch, TN.

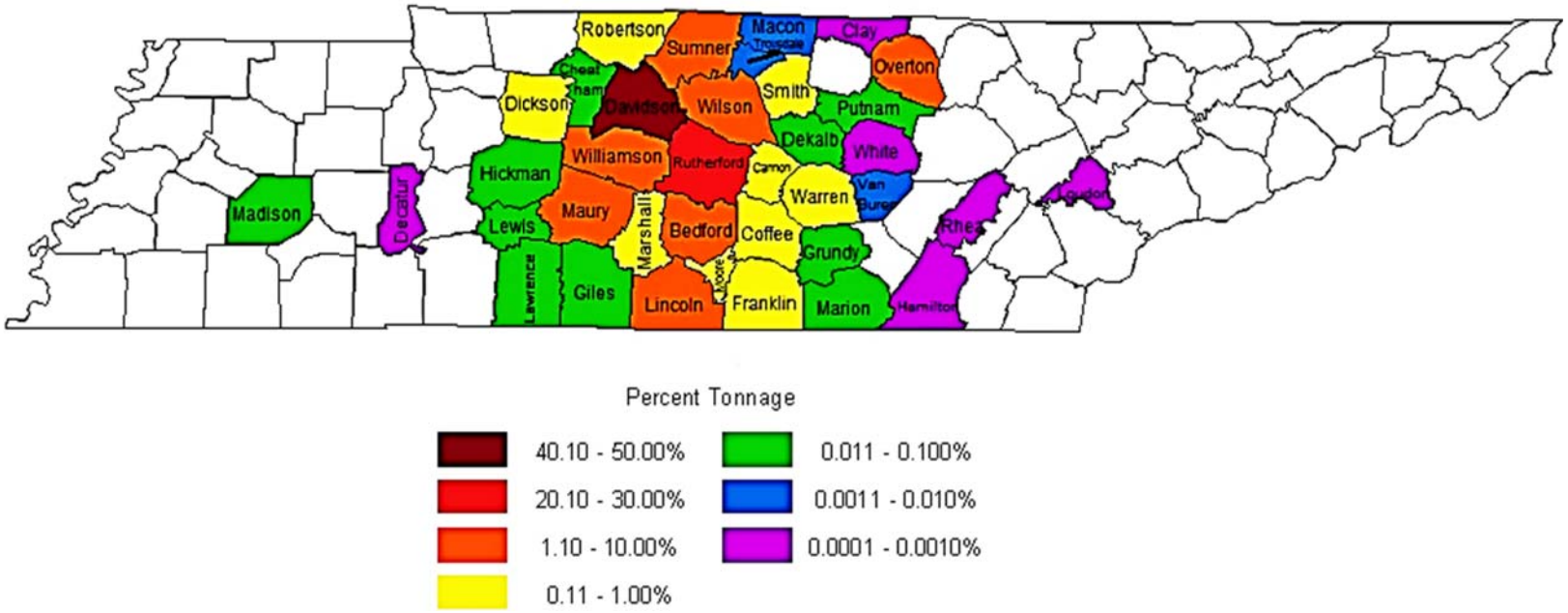

Figure 5: Percent of Total Waste Tonnage Sent to Middle Point Landfill. Data Source: TDEC Annual Progress Reports

The revenue from Middle Point's tipping fees is a portion of the Rutherford County's solid waste department's budget. The solid waste department operates on host fees, some property taxes, and the reserves they have collected throughout the years (Nolen, Smith). In 1995, Murfreesboro City also made a deal with BFI and agreed to create a pipeline for them to send their leachate to the city waste water treatment plant in exchange for free collection and disposal (Gershman). Republic Services allows free disposal of the 96-gallon carts it gives Murfreesboro residents, but Murfreesboro City must collect it themselves (Nolen, Smith). Republic Services will collect or at least provide collection for any city property including schools, SportsCom, City Hall, Old Fort Golf Course, Old Fort Park, McKnight Park, Patterson and McFadden Community Centers, Murfreesboro police buildings, Murfreesboro Water and Sewer buildings and biosolid sludge, and any similar buildings that Murfreesboro City develops or acquires (Gershman). Murfreesboro City has free collection by Republic Services at each Murfreesboro City building and a convenience center where Republic Services provides bins (Nolen, Smith). Murfreesboro City has certain bins that they collect themselves. Rutherford County has 15 convenience centers that they have purchased their own bins for as well as trucks to haul them. All Rutherford County residents can come to the convenience center for free and dispose of their waste. Rutherford County hires drivers to dispose of the waste at the landfill and do not have to pay tipping fees. Though Rutherford County has the convenience centers set up to collect the residents' trash, there is a thriving private hauler business. There is no way of knowing how many private haulers operate inside Rutherford County. To operate as a trash hauler, they only need a

business license and a covered truck (Nolen, Smith). The last time the Rutherford County and Murfreesboro Solid Waste Directors observed main streets in Murfreesboro, they saw about thirteen to fourteen companies driving around collecting trash from households (Nolen, Smith). Residents pay these companies to haul their waste, and the companies provide curbside collection whereas Rutherford County's free disposal requires people to dispose of their own trash at a convenience center.

After Middle Point closes, the Rutherford County and Murfreesboro City's budget will have an $18 – 19-million-dollar deficit to pay for disposal fees, the cost of the transfer station, the operators and loaders to haul, and the cost of diesel fuel (Nolen, Smith). The average disposal fees for Tennessee is about $40 per ton, and Rutherford County will have to start paying this to someone. This equates to $14 – 18 million dollars to be paid in disposal fees for Rutherford County's entire disposal tonnage. The proposed transfer stations that the Solid Waste Directors believe need to be installed cost $11 million each station (Gershman). The annual payment for the borrowed money to pay for a transfer station would be approximately $1,691,275 (Gershman). The loss of Middle Point is not just the added cost of disposing the waste elsewhere, but it includes the loss of revenue for both the Rutherford County and Murfreesboro City's budgets and the current cost to operate the convenience centers and trucks. Currently Murfreesboro City is creating a solid waste fee that will equal $1.3 million dollars or $5 per city-collected can per month (City of Murfreesboro …). The purpose of this fee is to begin to offset the loss of Middle Point disposal. The loss of Middle Point will not be a cheap solution for any of the parties involved.

Environmental:

Today, Rutherford County is responsibile for the old County landfill and the Class III/IV landfill's post-closure monitoring for at least the next thirty years if not indefinitely. Part of post-closure care is a continuous reshaping and replacing of the natural gas wells about every four to five years (Nolen, Smith). This reshaping is required because the ground will constantly settle with the trash beneath squeezing out any airspace.

The post-closure monitoring mostly includes groundwater monitoring quarterly (Nolen, Smith). Rutherford County can only react to any leaks or problems at the old landfill (Nolen, Smith). One of the major concerns with an unlined landfill is leachate pollution. Leachate is a natural byproduct of decomposition. When waste is left to sit and decompose either with or without oxygen, a liquid begins to come out of the material. The problem is when this liquid carries harmful toxins into the groundwater or closest waterway. One of the regulations for landfills is that any water that touches its property must be collected and cleaned before it can be released into the waterways (Nolen, Smith). The quarterly water tests completed by a third-party private company from Nashville – measures for metals, organics, or inorganics that accumulated from the leachate pollution (Nolen, Smith). Part of the infrastructure of a landfill involves leachate and rainwater collection ponds near the edges of the property line (Nolen, Smith). At Rutherford County's old landfill, they had to retroactively install these ponds which must be pumped and removed regularly. This process is relatively expensive per truckload (Nolen, Smith). A truck then takes the leachate to Murfreesboro City's waste water

treatment facility. Their leachate is clean enough that it does not have to be pretreated before entering the waste water treatment process beyond a shredder to reduce the size of any sediment in the load (Nolen, Smith). The next eleven years of leachate removal should cost $6 million (Nolen, Smith). Leachate used to be one of the biggest public health concerns with the old county landfill, but today gas migration has become the most concerning problem (Nolen, Smith).

For organics to decompose it needs air and water. Landfills are built to prevent air and water from entering, which mostly stops decomposition. Except that the organic waste is still able to decompose anaerobically or without oxygen, the byproduct is called landfill gas. Where the byproduct of aerobic decomposition is carbon dioxide, the byproduct of anaerobic decomposition is methane. Methane gas is nearly identical to natural gas, a fuel often used to replace coal in today's power plants. One major problem with landfill methane gas is how "clean" it is, which decides what a landfill owner can do with it. According to the EPA approximately 50% of landfill gas is methane, 50% is carbon dioxide, and a small amount is non-methane organic compounds ("Landfill Methane Outreach Program (LMOP)").

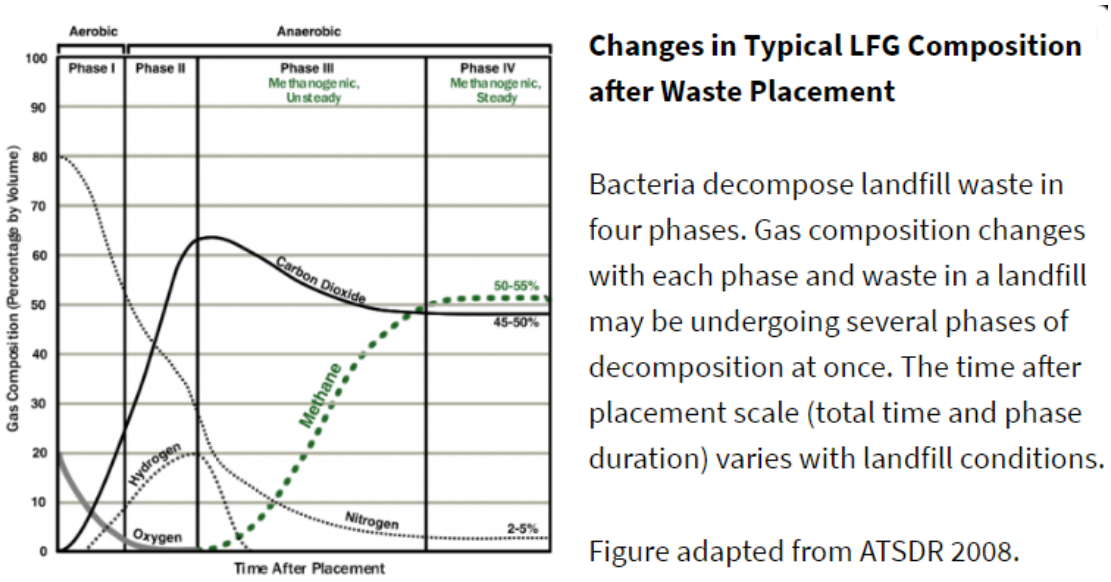

Figure 6: Changes in Landfill Gas Composition after Time. Data Source: *Chapter 2 Landfill Gas Basics*. Agency for Toxic Substances Disease Registry. Print.

Two popular solutions are either cleaning the landfill gas and turning it into energy or flaring the gas. Landfill gas is dangerous if left untouched because methane is 28 to 36 times more effective greenhouse gas than carbon dioxide over a 100-year period ("Landfill …"). Tennessee is particularly susceptible to landfill gas migration because of the karst geologic environment. The Tennessee Department of Environment and Conservation (TDEC) inspects the county landfill quarterly, but since Middle Point is inspected monthly TDEC often inspects the county landfill at the same time (Nolen, Smith).

All landfills have environmental standards concerning vectors that they must follow. Vectors are any organism that can carry diseases or spread the waste from one location to around the surrounding area. Some of the main vectors in Tennessee are scavenging birds like buzzards, seagulls, insects, mice, rats, and any feral animals. For a

landfill, the main preventative measure they can take is ensuring their daily cover is thorough and has no leaks or tears. Neither Middle Point nor Rutherford County landfill has any special techniques to prevent scavengers such as trained hawks to hunt the scavenging birds. Some landfills keep their open face very small, partly to keep in control of the shape and trash litter, but it can also benefit reducing vector presence.

Social:

Two social problems that have arose from Middle Point and Rutherford County's landfill are odor and borrowed soil. First, the stench that is constantly coming from it. The stench comes from the trash on the open face. Because Republic Services' alternative daily cover does not seal fully, smell is able to leak out throughout the night (Nolen, Smith). Even though this seems like a simple solution, Rutherford County does not have enough soil to give Middle Point to let it cover the face like landfills usually do. Republic Services has installed a misting system to attempt to reduce the smells (Republic Services).

Second, Middle Point already purchases a large amount of soil from surrounding areas to use called borrow pits. With a borrow pit, the landfill agrees to purchase the soil from a given property and promises to return it at some point in the future (Nolen, Smith). Refilling of these old pits can be dangerous because the ambiguity of the dirt's contamination levels. The Matthews farm, an adjacent property to the landfills, was purchased for soil, and the Reeves property beside the Matthews farm also sells dirt to Middle Point (Nolen, Smith). This is a social problem because as more trucks enter and leave the landfill their roads and peace of surroundings are deteriorated. This soil is

necessary in areas to prevent slope degradation and releases some carbon dioxide into the air like agriculture when over-tilling soil. These borrow pits do not help with people's mistrust of the company because originally there was not a time limit set on when the company had to refill these borrow pits (Nolen, Smith). Some of the older pits are still empty through today, and it is ambiguous to tell when the pits will be filled in and with what soil. The newer contracts have a limited time for Republic Services to replace the dirt on their property (Nolen, Smith).

Third, waste and landfills are essential utilities to our lives akin to electricity, water supply, and sewer facilities, but waste is not treated the same. When discussing disposal problems, the first problem that must be addressed is the lack of care people have for how waste is disposed, but the large amount of care they have for where it is disposed (Nolen, Smith). The phrase, "not in my backyard" (NIMBY) has become synonymous with landfills. Some techniques to avoid some of the NIMBY backlash is to create a community benefit agreement or have imaginative, high quality designs and architecture to make it more acceptable to the community (Cohen). Most people understand that waste disposal is a necessary public service, however there is a lot of mistrust between large corporations and the citizens. To earn people's trust, operations need to be transparent and constantly update the community to changes.

People have a lot of emotion when talking about waste disposal. It seems that people do not make logical decisions concerning solid waste, which impacts the efficiency of Rutherford County's decision (Nolen, Smith). When prompted for solutions, many of the commissioners who represent the citizens' opinions cite that the landfill

needs to be in someone else's county, and Middle Point needs to close despite the cost. The people feel like they have been lied to and used over the years. They need solutions that have benefits for them like increasing their property values, increasing their quality of life with odor problems, and make them involved and heard.

Analysis of Waste Diversion Technologies:

Recycling Situation:

To fully understand today's current waste situation, the recycling market needs to be considered. Recycling is a full-scale, global commodity business that fluctuates with supply and demand like the gold business or natural gas business (Westervelt). Today the world is facing the reality of a desperate situation. China, a major importer who created demand for recycling since 1992, has now dropped out of the market. Formerly, China was taking 42% of global plastic and 4,000 recyclable containers a day from the United States (Carrig). When China enacted its National Sword Policy, an environmental standard that banned the import of 32 recyclable commodities (mixed paper, plastics, etc.), it reduced the allowed contamination to 0.5% threshold levels China's imports and reduced imports to 3% of the previous global supply ("Global Recycling Industry Updates."). For perspective, Waste Management states that the average contamination rate for the communities they serve is around 25% (Bell). Currently the United States has felt most of this impact in the plastics market, however the same ramifications are happening in the paper market as well. Global impacts include the commodities market decline, taxes and bans on unprofitable plastics, stockpiling or landfilling recyclables, development of domestic infrastructure, quality assurance technology innovations,

recyclers incurring higher costs and placing higher contamination fees, and manufacturers using raw materials instead of recycled ("Global Recycling Industry Updates.").

The recycling commodities market is a driver and a challenge to the global solid waste issue. Today's recycling commodities market is volatile with the new requirements set by China (Hoornweg). China's new policy has drastically lowered all recycling values and inhibited companies from being able to move their recycled products out of storage. In the recycling commodities market, the warehouses that collect the recycling are supposed to collect, sort, and deliver the commodity to the next processor or manufacturer quickly. Their utilities are not built to hold onto the recyclables like they now do. Across the United States, warehouses and parking lots are being filled with bales of unsellable recycling collections. According to one handler in Massachusetts, 75% of what they collect they pay the next processor to take (Esch). The best recycling facilities still have 3% contamination, and these facilities are maintained by the larger recyclers in the market like Republic Services and Waste Management (Esch). The larger companies are researching and developing how to reduce the contamination levels at their facilities and at the customers' level. Some of the smaller companies are being bankrupted by this economy. Fallen recycling prices plus low prices for oil, a major ingredient in plastics, make this economy low profitability today (Esch). Waste Management reported an average price decrease of 43% for recyclables in the past year (Esch). Republic Services stated that last year, they received $100 per ton of mixed paper, and today they pay about $15 per ton (Esch). A very realistic option that the recyclers can consider and are doing is

landfilling these recyclables after collection because they are losing money and warehouse space to store unsellable bales of commodities. Considering, Rutherford County sends its glass and plastic recycling to the Waste Management facility in Rivergate and Riverhills, this is discouraging news for the local recycling outlook (Nolen, Smith). For Rutherford County, nine out of fifty recycling trucks from the schools over the summer were able to be recycled because of contamination (Nolen, Smith). This means that only 18% of recyclables were able to be recycled because people threw non-recyclables items or food into them to the point that the whole bin was wasted.

All of China's requirements and the downturn of the recycling market is because of contamination. Contamination is any material that is not the exact recycling material requested or any material that is deemed trash because there is no market to sell it in. Contamination differs based on the recycling market and what facility is receiving the recycling next. Some places can process plastic bags and the other types of plastic, but with the current economic environment and the local facilities, Rutherford County is limited in what it can and cannot recycle.

A major problem with contamination is a lack of education and well-meaning people trying to "wishcycle". Wishcycle is when a person places a nonrecyclable item in the recycling bin hoping that it can be recycled (Robinson). The act of recycling does not occur when a person places a plastic bottle in a recycling bin. It occurs when the plastic goes through the entire process and replaces virgin material in a manufacturing facility (Robinson). This is a fundamental disconnect that needs to be remedied, but it is difficult because the person who placed the bottle in a bin has done their portion of recycling. The

first interaction of placing the bottle in the bin is one of the most important steps to getting the rest of the process correct. However, if the first step is done incorrectly it sabotages the entire process and tons of other recyclable material from being recycled because it will be too contaminated to use and ultimately landfilled. A material is not recycled until it replaces virgin material in another product, and it is up to the consumer of that good to do everything in their power to limit contamination and provide the best material possible to let that material replace virgin material (Robinson). As more of these nonrecyclable items go through the process, the cost of recycling in general increases not including the already rising costs of higher processing because of China's new threshold levels (Robinson).

A curbside collection has often been cited as a solution to increase recycling. This is correct. Curbside, single stream recycling usually always increases recycling participation, but it also increases the contamination levels in the recycling (Esch). Single stream recycling method is where all recyclables are put into one bin for someone to pick up and take to the recycling facility, which increases the possibility of contamination.

In Rutherford County, the plastics market has limited profitability. The plastics type three thru seven have no value, making them trash and contamination in the recycled plastics bin for Murfreesboro City (Nolen, Smith). Table 2 is a summation of Rutherford County's Recycling requirements of accepted material and contamination.

Table 2: Summation of Rutherford County's Recycling Accepted and Contamination

Material	Accepted	Contamination (Goes in Trash)
Plastic	Food & Beverage Containers Dry Cleaing Bags Shampoo Bottles Medicine Bottles Window Cleaner Bottles Detergent Bottles	Plastic Bags Food Wrappers Candy Wrappers Styrofoam Motor Oil Bottles Antifreeze Bottles Pesticide & Herbidcide Bottles All other Plastics
Clear Glass	Clear Beverage Containers Food Jars Wine & Liquor Bottles	Pyrex Containers & Ovenware Light Bulbs Ceramic Cups, Plates, Bowls Drinking Glasses Mirrors Window Glass
Colored Glass	Colored Beverage Containers Food Jars Wine & Liquor Bottles	Pyrex Containers & Ovenware Light Bulbs Ceramic Cups, Plates, Bowls Drinking Glasses Mirrors Window Glass
Metals	Tin Cans Lids Copper & Stainless Steel Aluminum (No Cans)	Garbage Non-Metal Materials
Aluminum	Beverage Containers Lids Clean Aluminum Foil	Food-Contaminated Aluminum Foil
Mixed Paper	Newspapers Magazines Brown Paper Bags Printer Paper (Any Color) Junk Mail Wrapping Paper	

Data Source: Observed postings at Rutherford County Recycling Center

Currently Tennessee has a mandate to have 25% waste diversion by 2025. Including industry and commercial waste streams, Rutherford County surpasses this requirement. However, when only considering residential waste, the diversion rates are only at 14% (TDEC Annual Progress Report). Industry and commercial operations have stricter requirements set on them, meaning that any waste that leaves their facility must

be treated as potentially dangerous including general office waste. Residents have an easy time with waste, and this lack of control is showing in the residents' waste generation levels

The reason Rutherford County continues to collect recycling is because of public opinion, and they use it as a cost avoidance benefit to avoid the queue lines at Middle Point Landfill (Nolen, Smith). The profitable recyclables are the ones that can be recycled inside the county such as paper, aluminum, and metal. The plastic and glass recyclables are taken to Waste Management in Nashville for a loss. On average, Rutherford County spends $500,000 in operations and collection, and they generate $350,000 of revenue (Nolen, Smith). With the current recycling situation, investing in a recycling facility or curbside recycling is a huge risk, but Rutherford County residents heavily advocate for them instead of the landfill.

Material Recovery Facility:

A short summary of a recycled plastic bottle's life is being put into the recycle bin, going to the material recovery facility where it is sorted and compressed into bales, sold as bales to different manufacturers, broken out of the bales, washed, shredded into little pieces, heated up into strands, chopped into pellets after it hardens, and used with virgin material to form new products ("The Recycling Journey … "). In today's economy the plastic is stopping at the second step. The material recycling facilities are struggling to get anyone to purchase their bales of recyclables because virgin material is cheaper than going through the washing and shredding process at this point.

For example, Williamson County has their own material recovery facility (MRF) that they run with a private corporation. It was first built in the 1990s. Williamson County has a 30,000 square foot facility. All the machines that sort and bale the recyclable material is housed inside. On the left side of Plate 2, there are a few bales sitting outside waiting to be collected.

Plate 2: Williamson County MRF. Data Source: Google Earth Images

As seen in Plate 2, a MRF can be very complex. At the core a MRF is a multitude of different technologies designed to separate out the different recyclables and bale all like materials together for easier transport.

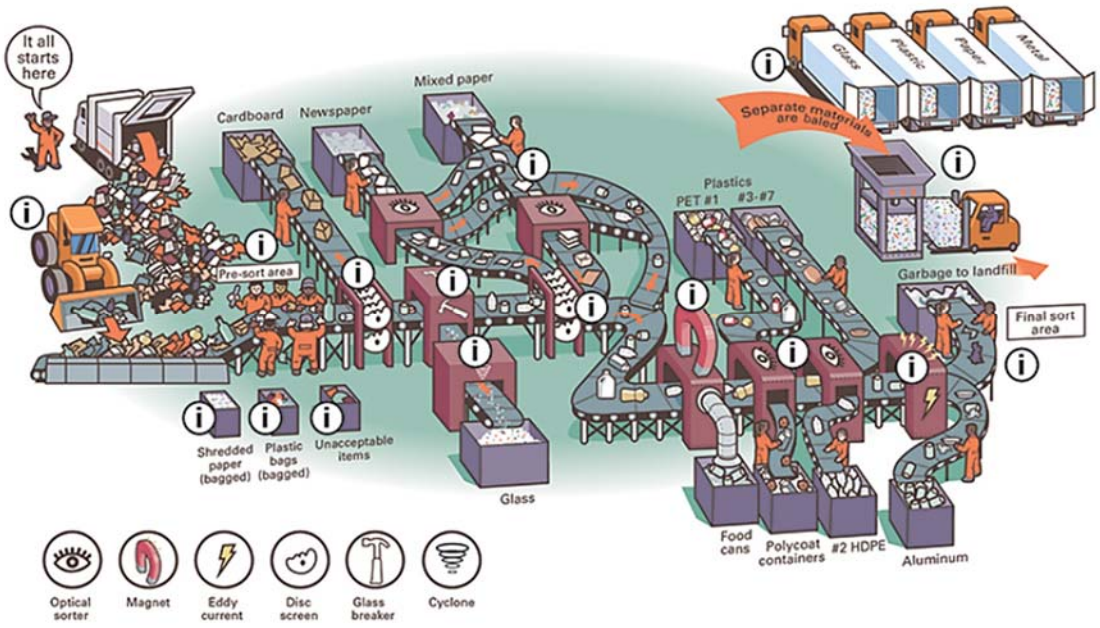

Figure 7: MRF Facilities Layout. Data Source: "The City of Calgary – Recycling Sorting Facility."

First, the material is placed on a large tipping floor, which is a floor space large enough to hold the day's waste collection and have space to spread enough to inspect it (Dubanowitz). At this point, the material is inspected for obvious contaminants and pushed onto the conveyor belt that drives the whole process (Dubanowitz). The conveyors are set to run very quickly just at the point where the workers can keep up. This is one reason why newer MRFs are beginning to include machines for sorting instead of workers because of health and safety liability and increased efficiency. In this presort area, workers will pick out unrecyclable items and plastic bags. Plastic bags often get caught in the mechanics spinning motors, which if it happens stops production to remove the bags from around the machines. They are removed at this point before they can cause damage. The order of the separation depends on the waste mix that comes in.

Ferrous metal separation can either be performed by hand or by magnetic technology (Dubanowitz). Glass is identified by machines with optical sorters (Dubanowitz). Optical sorters are a type of technology that uses light to reflect and "see" what color the glass is and separate it accordingly. Because to be valuable, glass must be separated correctly with little to no contamination. After the glass is sorted, some facilities have the glass broke and tumbled to remove sharp edges and make the glass more manageable when attempting to bale it (Calgary). According to the Calgary image, cardboard is separated by size compared to other recyclables, because it is thicker material (Calgary). The rest of the paper is sorted by other optical sorters that have been taught to recognize the different material. Technology today can be taught by identifying accept and rejects in its system, effectively teaching what it is and is not allowed to accept in the future. Plastic sorting is also completed through optical sorters, though they have additional color sensors on them similar to the glass sorting (Dubanowitz). Some of the lighter plastic can be moved by air and will move the lighter plastics to one section, and the heavier material stays on the conveyor to another section (Dubanowitz). After the sorting, there are bins containing loose recyclable material. This material is put into a compactor and is strapped and baled to be delivered to the manufacturer (Dubanowitz). Baling makes the material more manageable and allows higher volume of material to be sold at once.

Recycling does have some environmental effects that people often do not consider. The advantages include reduced energy consumption because the amount of energy required to manufacture certain products is reduced, decreased pollution because the amount of waste going to landfills is reduced, can slow the rate of resource depletion

in the way that successfully recycling paper can reduce deforestation and mining for the raw materials, and reduces greenhouse gases that come from landfills or burning methods ("Advantages & Disadvantages …"). For disadvantages recycling is not always cost effective because it requires a huge start-up cost with all of the infrastructure and multiple manufacturing plants needed to repurpose some materials, increased greenhouse gas emissions in the case of building factories and transportation across the country, needs higher participation to make an effective impact on the world's current waste situation, is often of lesser quality because as a material when reused and stretched it loses strength and durability compared to new material, and its collection sites can have health and safety problems considering it is an additional location for waste to be stored attracting vectors and risk of leachate concerns ("Advantages & Disadvantages …"). A recycling facility must take precautions with odor, water quality and vectors. Since the facility will have some waste sitting around, there is a chance for odors that need to be addressed with negative pressure ventilation to reduce the smell in the space or at least face away from any surrounding neighbors. A MRF must treat any water that touches the waste as leachate. This is more manageable than the landfill because the material should be under cover, but a collection system must be in place and creates a risk for spilling at some point. This is another location for waste to sit, which carries the risk of attracting vectors towards it. The facility would need a well-managed pest control system. Overall the disadvantages are manageable, but the benefits are not reaped without large demand in the recycling market. The increased recycling market hides a perverse incentive of increased, disposal consumption (Westervelt). Instead of people focusing on reducing

their waste generation, there is an opportunity for people to feel better about how much they consume because it is recyclable and still not entering the landfill.

For Rutherford County to build a material recovery facility (MRF) would cost approximately $25 – 30 million dollars (Nolen, Smith). The MRF would cost $75 – 100 per ton and improves recycling by about 10 – 15% (Gershman). Plus, the MRF would need a land space large enough for the facility itself, a warehouse to store bales, all the technical machines, and a truck dock (Nolen, Smith). Gershman, Brickner, and Batton (GBB), the third-party advisor hired by Rutherford County, included the development of a MRF in the expansion of Middle Point option (Gershman). Curbside recycling is not a reasonable option until Rutherford County builds a MRF of their own or the recycling market becomes highly profitable. Today, a projected startup cost for curbside recycling in Murfreesboro City is $5,156,000 not including the extra processing fee for co-mingled recycling loads or trucking costs to Nashville's MRFs (Smith, Joey).

Composting Facility:

The most popular example of composting that Rutherford County officials are considering is the Sevierville City Operation. Composting is creating the perfect conditions for natural decomposition to take place in the solid waste (Freudenrich). It puts the organic waste in soil with available water and air which releases carbon dioxide and heat, then the finished product "compost" can be used as fertilizer to any soil (Freudenrich).

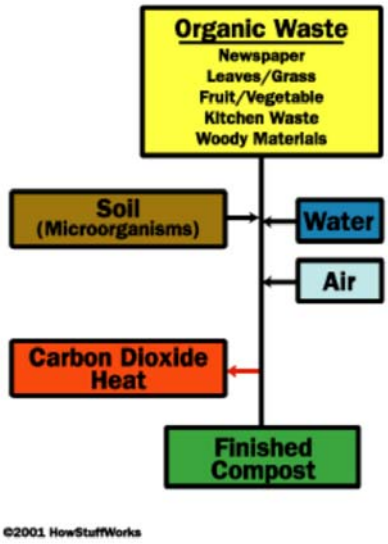

Figure 8: How Organic Waste Decomposes to Compost. Data Source: Freudenrich, Craig. "How Composting Works" *How Stuff Works.* Web.

In Sevier county, they place all of their solid waste into the composting facility, not just the organics. Pictured below is the 172,000 square foot composting facility.

Plate 3: Sevierville Composting Facility. Data Source: Google Earth Image

The first step of the composting process is a truck entering the facility and placing the load on a tipping floor where workers visually inspect the waste for unacceptable

items or too large items. Some of the unacceptable items include oil, barrels, drums, hoses, cables, wires, rope, bungy cord, tarps, construction and demolition waste, car and truck batteries, auto and gas tanks, medical waste, hazardous waste, paints, chemicals, and carpet (House). The Sevierville compost facility specifically adds in the sewage sludge from the local waste water treatment plant and rejected candy from the candy factory to add sugar to the process, which the bugs in the compost thrive on. The facility also adds a soil additive called Vitazyme (House). After being mixed thoroughly, the waste is placed into one of five Eweson digesters which each is a large cylindrical tube that rotates at fifty revolutions per hour (House). The rotational effect of these tubes breaks up and mixes the waste material. These tubes are depicted on Plate 3 at the bottom of the image. The waste is moved through these tubes for three days with the prior day's material moved to the next section at the beginning of each day (House). The temperature in these tubes reach 160 degrees Fahrenheit which increases the decomposition of the organic material and sanitizes the waste inside (House). After the Eweson digester, the waste is put through a twenty-two-millimeter screen (House). Any material that cannot go through this screen is inorganic and is taken to be further processed for recyclable materials and/ or eventually landfilled (House). The material can go to the Class III landfill because the heat from the digester sterilized any microorganisms, and organic waste is seen as the most dangerous in a landfill. The third step of this facility is to set the waste into windrows inside the covered warehouse (House). The compost stays in these windrows for twenty-eight days being turned over by machinery periodically ("Composting."). In this third step, natural decomposition is taking place in the compost.

This encourages the growth and maintenance of microorganism and worms to create a healthy environment for them to thrive and continue to eat at the waste (Freudenrich). Composting is not a deeply complex or mechanical process. The main technologies besides the first digester is the air cleaning processes they must maintain to reduce the smell. This technology is called a Biofilter and is a mulch material that all of the warehouses' air must pass through before being vented and naturally cleanses itself of any bacterial/ viral pathogens, dust, odors, spores, or volatile organic compound gases produced from the waste decomposing (House). This is an important health and safety concern for a composting facility like this. The fourth step is after the sitting period, the waste is put through a nine-millimeter screen again removing any material that is larger and disposing of it in a Class III landfill (House). This final product compost has Grade A status ("Composting."). This compost can be used on any farms or land areas including food production. The compost is tested for presence of pathogens, heavy metals, and hazardous waste toxicity characteristics (House). If the process is well-managed the risk of contaminated compost is reduced.

Composting is a good investment because it diverts waste out of the landfill thereby reducing all of those negative environmental problems. However, composting still has some environmental concerns. The biodegrading waste is a food source for many vectors from flies to rats to raccoons (Profita). A composting facility will need to be set up with pest reduction measures such as fences and a contract with a pest company. Another concern is the odor that comes from the facility, but there are several different technologies to combat this such as negative pressure ventilation and the biofilter that

Sevierville uses (House). The placement of a composting facility would need to be directed away from the closest neighbors to reduce the waft of odors toward them. Any water that touches the compost piles will have to be collected and treated as leachate before it can go into the natural waterway. One problem composting has had before is the possibility of contamination in the final fertilizer product. Contamination from any herbicides, pesticides, personal care products, toxins, or pathogens can go through the composting system and make it into the final product (Vinje). The Eweson digester helps prevent some of these contaminants, and the final product testing is continuously occurring to ensure that none of the compost was contaminated (Vinje). However, this is a common assumption of compost and waste water treatment sludge facilities that Rutherford County will need to address if they choose this as an option.

Sevierville collects waste from Gatlinburg City, Sevierville City, Pigeon Forge City, Sevier County, and the Great Smoky Mountains National Park ("Composting"). Daily, the Sevierville composting facility takes in 365 tons of solid waste and can compost 60% of it (Broden). Sevier County has been very successful with their composting facility and handling their solid waste disposal, but there are a few fundamental differences between Sevier and Rutherford County that will affect composting's success in Rutherford County. Sevier County has approximately 97,000 residents and Rutherford County is approaching 317,000 residents. Population is a major influence on the amount of solid waste generated. Rutherford County's estimated daily tonnage today is 1,122 tons not including recycling compared to Sevier County of 365 tons. This facility would only handle 32.5% of the waste that Rutherford County

currently produces, and it is one of the largest composting plants in the nation. Another difference is that Sevier County is supported by tourism and Rutherford County has industry, office, residential, and commercial areas. This difference directly affects the waste composition of the county. Sevier County most likely has a lot of organic waste from the restaurants and tourism where Rutherford County has a more complicated waste composition between the different sectors residing in it. According to Nashville's waste study, approximately 32% of their waste is organics, which we can assume is comparable to Rutherford County (CDM Smith). There is a possibility that presorting organics out of the waste can be a solution. Although, the Solid Waste Directors had already considered composting as an option and obtained a TDEC compost permit, the TDEC permit only included taking compost from the county schools and the jail because the risk of contaminants in the household collection exceeded what the operation could manage (Nolen, Smith). Contamination could be contained with these limited sources and more easily controlled. The main problem is siting the facility because the compost itself needs to be covered, and there is no suitable site in Murfreesboro city area (Nolen, Smith).

The expected cost of the proposed Rutherford County composting facility according to the Solid Waste Directors would be $90 per ton (Nolen, Smith). Gershman, Brickner, and Bratton says that composting typically costs $25-30 per ton such as Sevierville (Gershman). Their annual operation costs are approximately $5.4 million with a $27. 50 per ton charge to cover (Broden). The composting cost for Rutherford County would be more expensive at the beginning, and considering Rutherford County can only collect from a limited amount of people compared to typical composting schemes, it will

be more expensive than typical facilities. Sevierville charges $40 per ton of solid waste from the private businesses, $30 per ton from public entities, and $12 per month for Sevier County residents (Smith, Xavier). This pricing scheme allows them a little savings amount for emergencies if the machines break or if the facility needs upgrades. Since its opening in 1992, Sevierville has paid a total of $25 million investment into the facility (Smith, Xavier). Though the composting facility is not as expensive as building a MRF, it is still a large investment that leaves Rutherford County with fertilizer that they will need to sell. The Sevierville Composting facility produces more than 98,000 tons of compost annually (Smith, Xavier). Assuming Rutherford County can scale up the production to match their waste disposal needs, they would produce more than 300,000 tons of fertilizer requiring a buyer to be located. Otherwise the facility would be overrun by storage.

Analysis:

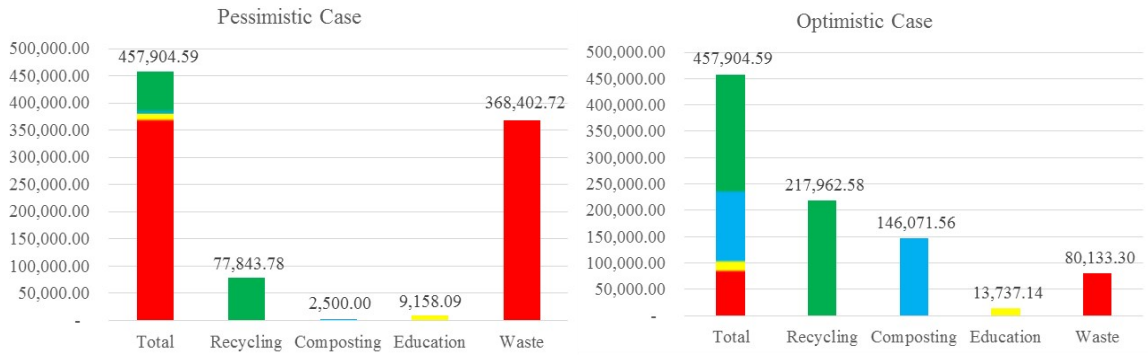

Figure 9: Pessimistic and Optimist Case of Waste Disposal: Data Source: TDEC Annual Progress Report and Gershman's report

Based on the Nashville waste composition these graphs show an optimistic and pessimistic case. Assumptions for the pessimistic case are that recycling stays at the

current 17% rate. The composting is only possible by the Rutherford County schools, the jail, and nursing home. Rutherford County currently collects 5,000 tons annually from these locations and assumed that 50% of the waste is organic (Nolen, Smith). The education impact is only 2% of entire waste stream. These assumptions lower waste down to 368,000 tons. Assumptions for the optimistic case is all of the recyclable compositions were recycled: glass, metal, plastic, and paper. The composting takes all organics at 31.9%. The education is successful at 3%. These assumptions lower waste down to 80,000 tons. In either case, Rutherford County's total waste generation demands to have a solution and cannot be ignored. At this point with today's technology, Rutherford County cannot be a zero-waste community though it is an admirable goal.

Rutherford County State of Affairs:

This report limits the scope of analysis to residential solid waste generated, assuming the volatile recycling market will not affect Rutherford County waste generation, and assuming Middle Point will remain in operation for the next ten years. Currently, Rutherford County disposes of 350,000 tons of municipal solid waste (MSW) to seven different Class I landfills spread around Tennessee. Rutherford County's population is expected to more than double by 2040 (Tennessee Department of Transportation). Though not many sources can agree what variables effect waste generation, population is an often cited increasing variable (Hockett). As more people come to one area, the waste generation naturally increases. Since 1980, Rutherford County increased 211% in population from 84,784 to 263,769 people in 2010 (TN Department of Transportation). The County population was relatively small when Middle

Point started operations in 1988. The permits were based on a significantly smaller population, and the host county and city contracts do not have growth stipulations built into them. Going forward, waste generation for Rutherford County is expected to increase at an average rate of 3.03% per year (Greater Nashville Regional Council). Rutherford County is responsible for 26.09% of the waste that goes into Middle Point. As the amount of waste generated increases, Middle Point's lifespan will decrease. This analysis focuses on residential waste because in 2015 residential waste was responsible for 88% of Rutherford County's waste disposal needs (Greater Nashville Regional Council). According to the TDEC Annual Progress Reports as seen in Appendix B, residential recycling and waste diversion is 8.03% of Rutherford County's total waste generation which includes recycling, waste diversion, hazardous waste, and solid waste. While the industrial sector is responsible for 34.84% of recycling and diversion. This report cites no solid waste generation from the commercial, institutional, or industrial sectors. This is because the waste generated by the industry or commercial sectors did not have to be treated specifically.

Currently Rutherford County disposes of 1,122 tons per day, and Middle Point takes 3,950 tons per day (Almanza). In ten years and one day, assuming a 3.03% growth rate, residents will produce 1,470 tons of trash and expect to be able to dispose of it. Rutherford County and the municipalities inside will be responsible of disposing of 457,904.59 tons of waste for 2027 and ongoing. The first step Rutherford County needs to complete is finding another place for the trash to be disposed. To effectively compare the costs of a new waste solution, Rutherford County needs a new baseline (Whitefield).

As a comparison for these baseline changes take new lighting options for a building as an example. Originally this building was lit by daylight, a virtually costless situation. Now, the cost and energy savings between lighting the house with lightbulbs needs to be calculated. However, comparing any lightbulb against daylight is unfair. Moving forward daylight is not an option, the house will have to install infrastructure to be able to power the new lightbulbs. In the case of Rutherford County there is no infrastructure built to handle transferring the waste or collecting it to turn into energy or finding any demand for waste byproducts. Before Rutherford County can compare these alternatives, a baseline that already includes the infrastructure must be chosen. Choosing a new baseline alternative does not mean selecting that as the next step. The baseline is a feasible option that gives Rutherford County values to compare the costs against economic, environmental, and social factors. The problem with cost savings or energy reductions is that it cannot be measured. Any savings or reductions must be calculated by subtracting the difference from the alternative and relative baseline. If the daylight lit home is the baseline, then any lightbulb will increase your cost comparably. However, if incandescent lightbulbs were a baseline then it shows an accurate comparison of electricity cost, useful life, and quality of light in the house. Rutherford County's waste situation is the daylight lit house, disposal fees are $0, collection is paid for by the government, and there is no infrastructure in place. If this scenario is the baseline, any alternative will appear negative and skew many of the comparison measurements. Because of this, Rutherford County needs an accurate baseline to compare their alternatives against. Choosing a new baseline does not mean deciding Rutherford

County's future. The baseline is simply a good comparison tool for other alternatives to be measured against. A good baseline comparison is one that economically is the least expensive, environmentally has little impact, and is socially acceptable.

Selecting a Baseline:

Gershman, Brickner, & Bratton (GBB) listed four options for Rutherford County: no changes, install transfer stations, expand Middle Point, and waste-to-energy. As previously discussed, "no changes" is an inadequate baseline comparison, so the other three alternatives will be compared for Rutherford County's new baseline. The selected baseline is not an actionable suggestion. It is simply a baseline that can handle all of Rutherford County's waste and have adequate infrastructure to help compare against the other alternatives. One unifying aspect between the alternatives is that any will require some form of landfill. There is no technology that can prevent landfilling, but there are increasing levels of technology that will reduce how much must be landfilled, prolonging the life of a landfill significantly. In this case, we need to look at Tennessee's available landfills where the waste can be alternatively taken.

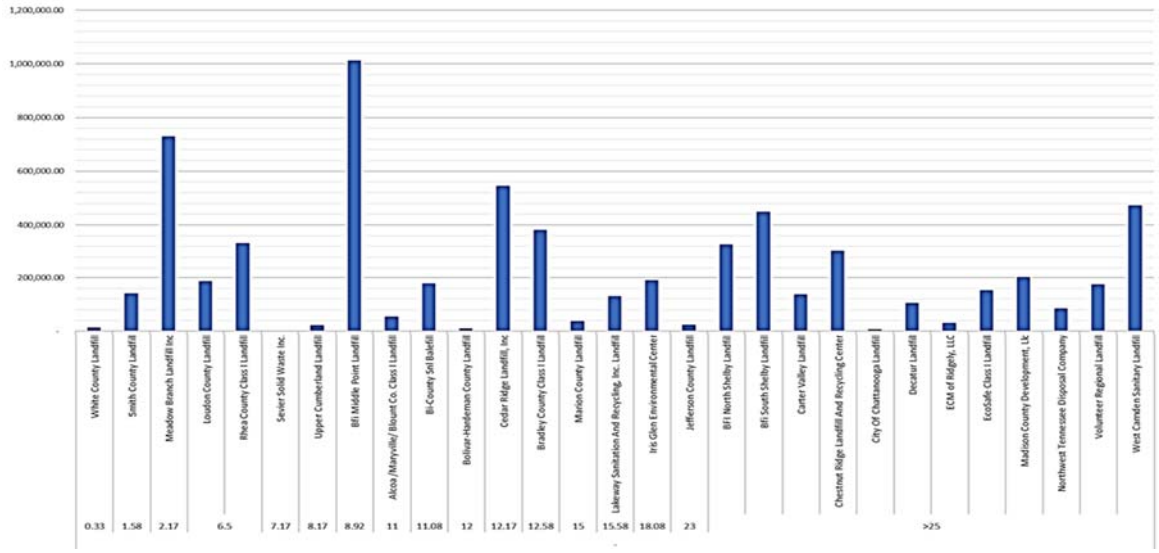

Figure 10: TN Class I Landfills Annual Tonnage and Life. Data Source: TDEC APR, EPA LMOP Database, and 2018 Remaining Life Survey

Middle Point is on a different scale than other Tennessee landfills. It collects over 1,000,000 tons of waste annually. The second largest landfill, Meadow Branch, collects over 700,000 tons, but it closes in two years. The third largest, Cedar Ridge, has a life expectancy of twelve years, but it only collects 550,000 annually. Appendix 3 has another graph to show the size of the landfills compared to Tennessee's overall waste disposal. Cedar Ridge is one of the first landfills Rutherford County can consider as an alternative for taking its waste, but Cedar Ridge can only handle half of the capacity of Middle Point not counting for the contracts Cedar Ridge already upholds. According to GBB's analysis, waste will increase to about 340,291 tons, but the analysis only considers the waste that Rutherford County currently sends to Middle Point landfill. Waste will increase to about 457,905 tons using 3.03% growth rate and considering the total waste that is landfilled by Rutherford County to any landfill. At this point, Rutherford County

would produce 84% of Cedar Ridge's capacity assuming they accept the same amount of waste then as they do today. Once Middle Point closes, without a new landfill opening or an existing landfill expanding its capacity, there will be a shortage of landfill space for the waste generated.

Transfer Stations:

GBB called the transfer station option, the "Maximum Flexibility" option because it installed the infrastructure the county will need going forward, but it did not include investing in any hyper-specific technology.

A transfer station is a place to screen waste before disposal, provide flexibility in future waste disposal options, and can be used as a convenience center as well (United States). However, it cannot be the other way around. Convenience centers are not considered transfer stations because often they cannot handle the quantity of waste a self-unloading collection truck discharges (United States). Though it seems like the easiest solution to expand one of these locations into a transfer station, the land amount needed is exponentially higher than these convenience centers currently hold. To build a transfer station, Rutherford County needs to plan, site, design, estimate operating costs and compare to the reduced hauling costs (United States). Transfer stations can handle municipal solid waste, yard waste, recyclables, household hazardous waste, and construction and demolition debris (United States). Transfer stations can act as a location for source reduction programs to flourish. Instead of having multiple sites with a little impact at each location, sorting at the transfer stations will have an impact on the largest amount of waste. Using transfer stations has economic and environmental benefits. One

is that as the waste handlers sort the waste more efficiently, then the drivers' costs will decrease, and the recyclables could bring some additional profit. Also, waste going to the landfill is reduced, prolonging the life of the landfill and reducing its impact. The transfer segment of transfer stations can be completed by transfer trailers, intermodal containers, barges, or railcars (United States). At minimum the transfer station would need to be able to have enough tipping floor space to hold a full day's waste in case of trucking emergencies (United States). The EPA estimates 4,000 square foot plus twenty square foot per ton delivered (United States). Assuming 1,468 tons of waste daily divided into two transfer stations, one transfer station would need to have 18,680 square feet of floor space in case of any emergency. To be the most beneficial, the site selection needs to be relatively close to where the highest amount of waste is generated (United States). If the transfer station is placed away from everything, it has a smaller social impact on the community, but it decreases its economic and environmental efficiency because the trucks will have to drive a longer distance. Typically transfer stations have a buffer space between themselves and their neighbors, enough road space for large trucks and queue lines, space for the source reduction areas, and sloping topography for multilevel building compatibility (United States). The site has to be sized to hold all the waste, access to utilities, and limited environmental impacts (United States).

Transfer site designs include a tipping floor with tunnels and ramps for the transfer truck and loaders to move around, buildings that fully enclose the process, parking areas, public conveniences such as recycling and general public trash drop-off, public education center, space for future expansion, holding areas to handle inappropriate

waste loads, and the scale house that all of the incoming vehicles must enter and exit on to weigh and collect fees (United States).

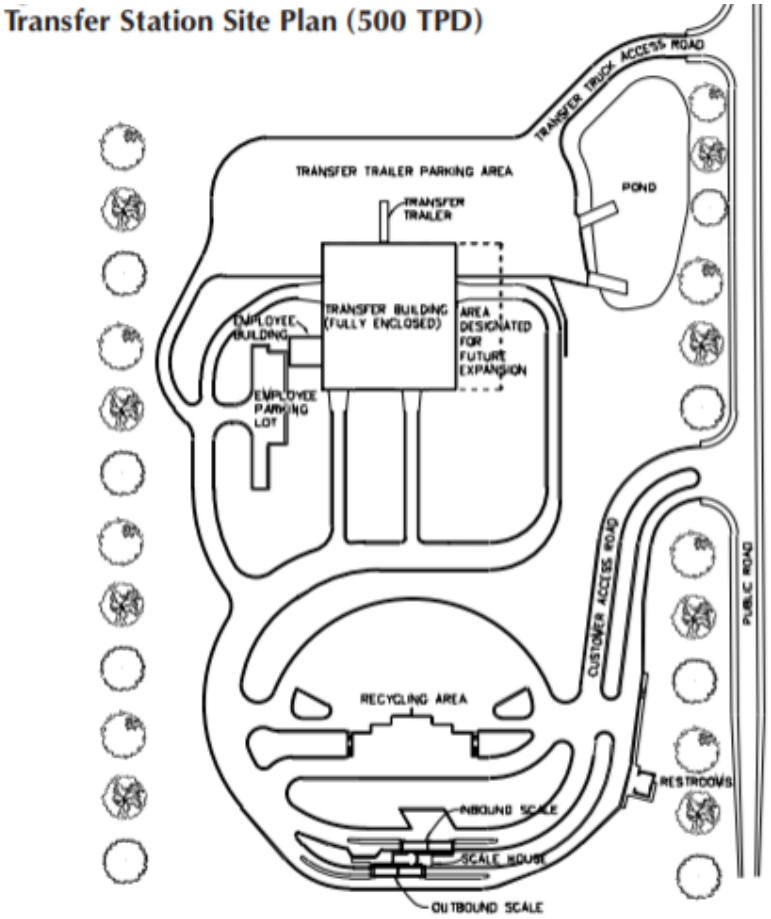

Figure 11: Transfer Station Site Design. Data Source: United States Environmental Protection Agency. Waste Transfer Stations: A Manual for Decision-Making, 2002.

Following the flow of trash, the truck enters in from the road and is directed into the recycling convenience area. Though some people charge for recycling as well, it would create better incentives to keep the recycling area free. After the truck is directed into the recycling convenience area to dispose of any specific recyclables or organics, the

truck next goes to the entrance scale where it is identified and marked by weight. Next, it drives into the enclosed transfer building where it will dump its contents onto the tipping floor. There are several designs for the tipping floor and how it is put into the transfer trailer. Finally, the incoming truck goes back to the exit scale and is weighed again. The difference in its weight decides how much it is charged per ton.

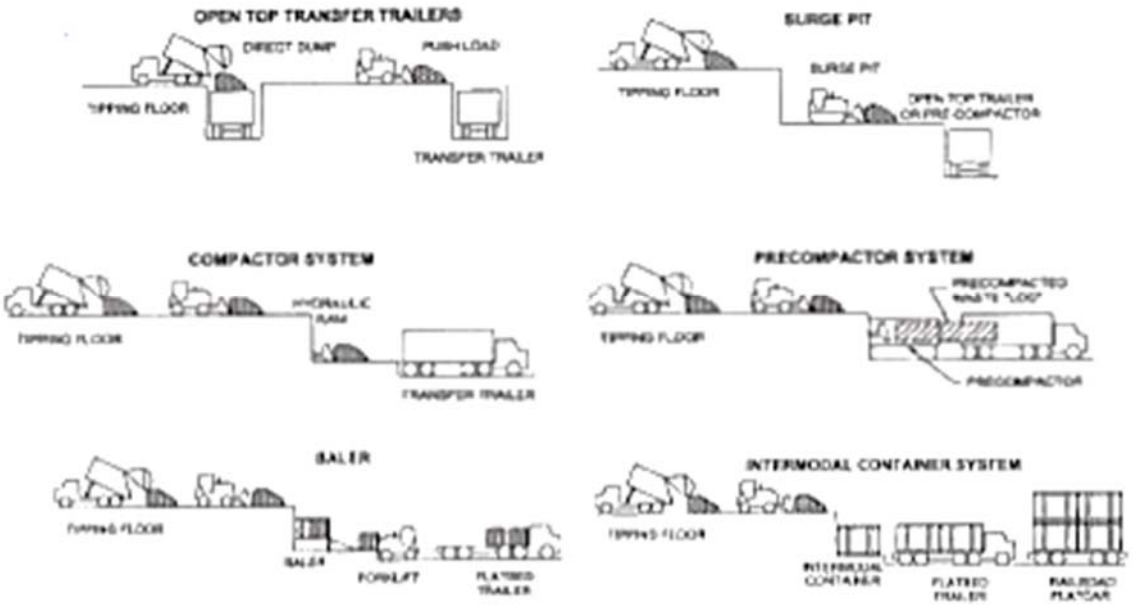

Figure 12: Tipping Floor Comparison Drawings. Data Source: United States Environmental Protection Agency. Waste Transfer Stations: A Manual for Decision-Making., 2002.

The tipping floor is designed differently based on the amount of waste incoming, how it will be transferred, and how much control the facility wants over what is wasted. Dumping directly into the transfer trailer prevents any sorting by the facility (United States). Since this sorting is one of the main benefits of a transfer station, dumping is a

rare choice. There are six basic types of tipping floors pictured above: push load – open top trailer, surge pit, compacter system, precompacter system, baler, and intermodal container system (United States). The *push load – open top trailer* is where the trash is dumped on the tipping floor, heavy machinery inspects and sorts the load for recovery, and then pushes the waste into the trailer (United States). The trailer is sitting on a level below. The surge pit is very similar to the push load except there is an extra vertical step between the tipping load and the truck. Now the *surge pit* sits two levels above the truck, and on the interim level is a pit that a loader can store some waste, reducing how many transfer trailers are needed, and slightly compact the waste before pushing it into the trailer (United States). The *compacter system* has a hydraulic ram built into the facility that the truck backs up into. The ram then has trash pushed in to compact the trash into the truck (United States). The truck must be heavier to withstand the ram which limits how much waste they can carry (United States). Trucks are only allowed to weigh a certain amount on the roads to prevent any undue damages or bridge failings. Trucks that are overweight travel the road at specific times of the day designated by a permit they must obtain and do not have as much freedom as the lighter trucks. The *precompacter system* also uses a hydraulic ram but the ram is used in the facility to create a dense "log" of waste (United States). The log is then pushed into the trailer, which allows it to be a lighter material truck and relies on a landfill tipper to unload by gravity when the truck reaches the landfill (United States). A better version of the compactor system, the precompacter system, allows more waste in a smaller space, raises the cost benefit as the truck does not have to be as heavy. The *baler* system uses a machine that can compress

the waste into self-contained bales, which then can be lifted by a forklift onto a flatbed trailer (United States). This allows another type of truck to deliver the waste. The baler has very high paybacks per load, but it is technology-intensive and thus more expensive and requires a high-volume transfer station (United States). The final system is the *intermodal containers*. Waste is loaded into intermodal containers, which are typically moisture and odor controlled, and this system is best if moving the trash by railcar or flatbed truck long distances (United States). The containers allow the waste to sit at the station until there is enough waste collected to economically move it all together (United States). The intermodal system is an interesting idea for the unique transportation options it offers.

Unless Rutherford County finds an ideal waste solution that is distanced farther away than the current landfill options and is in proximity to rail lines, the transfer stations will most likely be a surge pit with an option to install a precompacter at some point in the future when it is more economical. Though Rutherford County has a large amount of waste volume, the baler system seems too advanced for their needs.

With a transfer station, Rutherford County would have more control over where their waste goes. For instance, if they want a specific disposal method such as waste-to-energy, then consolidating all the waste to deliver at once is easier than on the individual trucks (United States). With private haulers there is no mandate that the County government can impose on them. A way to influence private haulers is by providing a conveniently located transfer station that gives the control back to Rutherford County over disposal.

If the disposal facility is more than 15 – 20 miles away, then transfer stations become economically viable (United States). The tipping fee price is set by the owner or Rutherford County and is affected by the tipping fee cost at the landfill, cost to transport to at least achieve break-even profit, and cost of operating the transfer station. For example, the transfer station in Antioch has a $40 tipping fee, but the price in New Zealand is about $120 United States dollars. Figure 13 depicts viable landfill options for Rutherford County after Middle Point closes and assuming the 3.03% growth rate. The closest landfill is more than 60 miles away reaffirming that beyond a landfill opening within Rutherford County, a transfer station of some sort is inevitable.

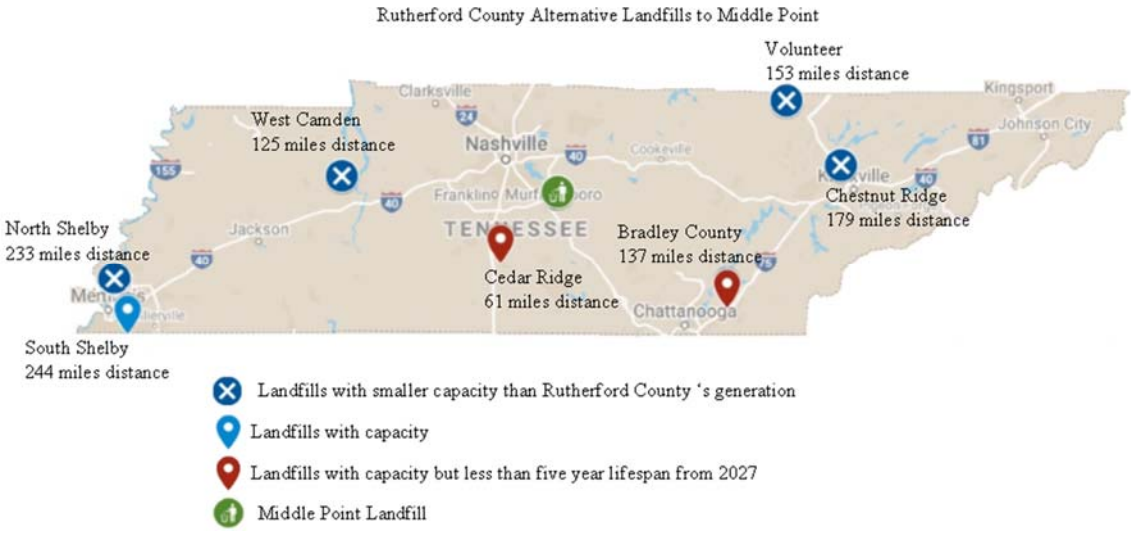

Figure 13: Rutherford County Alternative Landfills to Middle Point Data Source: TDEC APR, EPA LMOP Database, and 2018 Remaining Life Survey

For Rutherford County the proposed transfer station locations are at the current landfill in the northern corner of the county and a location in the southern portion of the

county near the Eagleville area (Nolen, Smith). However public committees and opinion is consulted before siting is finalized (United States). The community will be heavily involved in any step moving forward, including selecting the location for these transfer stations.

Though not full-fledged landfills, transfer stations still have environmental concerns that need to be monitored such as air emissions, water quality, and vectors (United States). Air emissions from transfer stations are monitored like those from landfills. Wastes that are particularly dusty, dirty roads in a drier area, or exhaust from the diesel trucks are air problems that occur at a transfer station (United States). To help reduce diesel truck emissions, the transfer station can require that drivers do not let their trucks idle as they wait in queue to dump (United States). Additionally, the transfer trucks should undergo routine engine maintenance or use alternative fuels used to reduce emissions (United States). Many landfills are trying to clean their landfill gas to be usable in truck engines, and there could be a partnership available here that could benefit both parties. For health and safety, the transfer building will need to install air filtering systems (United States). This can also help screen some of the particulates before they reach the atmosphere. Some facilities maintain misting systems to reduce their dust and odor on the waste before it leaves the building (United States). The misting system could be effective, but it would be better to use reused water because water must be specially treated here like it does in the landfill. Any water that touches waste must be collected and cleaned specifically as leachate (United States). Luckily unlike a landfill, the leachate collection should be much smaller in this facility because the only waste is in the transfer

building instead of the entire campus. The water that is contaminated with waste is comparable to leachate. Some leachate protocols may require pretreatment by the facility. The waste can be contaminated with any heavy metals or personal care products, so if there is any spillage into the waterway it must be reported. One way to design the station to prevent runoff is installing more pervious locations like grass or vegetative cover areas instead of a large amount of concrete or asphalt (United States). Asphalt only increases the amount of runoff in an area. Quarterly water monitoring will most likely be required like it is today. Vectors are any organism that has the potential to transmit diseases (United States). As waste collection facilities have a problem with scavenging birds, facilities must be built to reduce the enticement of this type of vector. The facility needs to have a pest management system, bird-deterrent measures, and routine inspections (United States). The easiest solution is ensuring there is no waste left at the facility overnight and a first in – first out mindset to ensure no waste sits for long periods of time (United States). Overall transfer stations are relatively harmless to the environment if there are good controls in place and the facility is kept clean.

Socially, transfer stations appeal to the public more than landfills. Public opposition is often high for new landfills near urban areas, and many cities find it costly to expand landfills and cheaper to transfer waste to a regional landfill in a rural area (United States). Traffic, noise, odor, and litter problems are “good neighbor” problems that still need to be addressed before they become problems for the surrounding citizens. While traffic is an environmental problem, it is a social complaint locally. The roads that these trucks frequent often degrade faster than others and litter remnants spread from the

line of trucks. There are ways to design the facility to ensure that the trucks do not queue on the open road or use roads that are not frequented by citizens often (United States). How large of a problem traffic is to the community might decide the type of tipping floor Rutherford County will choose to compact more waste into fewer trucks. Also, the noise of the operating transfer station represents a negative externality to close neighborhoods (United States). Throughout the day, heavy machinery will operate inside the transfer building, moving waste from the floor into trucks. A building made of concrete, if the buffer zone is sufficiently large, will offer some insulator value and reduce some of the traveling noise (United States). Another reasonable requirement is limiting the hours of operation to prevent noise at night (United States). Odor from the current landfill is already a common complaint in Rutherford County. Unfortunately, the transfer station will still have odor problems due to the municipal solid waste and organics sitting there waiting to be transferred out. However, solutions for vectors will work for odors as well. Reducing the time that waste sits at the facility and ensuring that every night the waste is gone and cleaned will prevent most of the odor problems (United States). Litter is the final complaint that comes with transfer stations, which is like the litter on the sides of a normal road but worse. Many of these trucks are not sealed but only have their load covered allowing lightweight objects to escape (United States). When siting the main transfer building, prevailing wind should be taken into consideration and ensure the doors inside the building are not facing it (United States). Beyond this, it is hard to prevent some litter spread, but it must be part of the facilities' daily routine to clean-up the daily litter to prevent any environmental damage or vector encouragement. It seems that if the

transfer station is kept in good condition and cleaned regularly most of the social problems are handled.

Waste-to-energy Facility:

There are three main types of waste-to-energy technologies today. One, thermochemical which involves a method of using high temperatures to recover energy from municipal solid waste (MSW) (Marshall). Thermochemical holds 88.2% of total market revenue of waste-to-energy facilities and includes processes such as combustion, gasification, or pyrolysis (Marshall). Second, biochemical conversion uses microbes to process and transform the waste (Marshall). These processes are restricted to only biodegradable waste or the moisture rich items that limit the other processes and involve anaerobic digestion, fermentation, landfill with gas capture, and microbial fuel cells (Marshall). Third is chemical conversion also called esterification which involves reacting different chemical compounds to produce biodiesel (Marshall). Waste-to-energy is a growing field of research, and the processes can get increasingly more complex. Rutherford County has researched and toured a local thermochemical example, a waste-to-energy facility in Huntsville, Alabama. Covanta's example is more applicable to Rutherford County and its municipal solid waste, then the other waste-to-energy types.

Covanta Huntsville Inc. is adjacent to the Redstone Arsenal where it sends the 180,000 pounds of steam it produces per hour for the Arsenal's heating and air conditioning ("Covanta Huntsville."). They process 690 tons per day which is about 251,850 tons per annum including the sewage sludge from Huntsville's waste water treatment plant ("Covanta Huntsville."). The system has air pollution control equipment:

flue gas scrubbers, baghouses, nitrogen oxide controls, mercury controls, and continuous emissions monitoring which allows for quick response if emissions alter quickly ("Covanta Huntsville.").

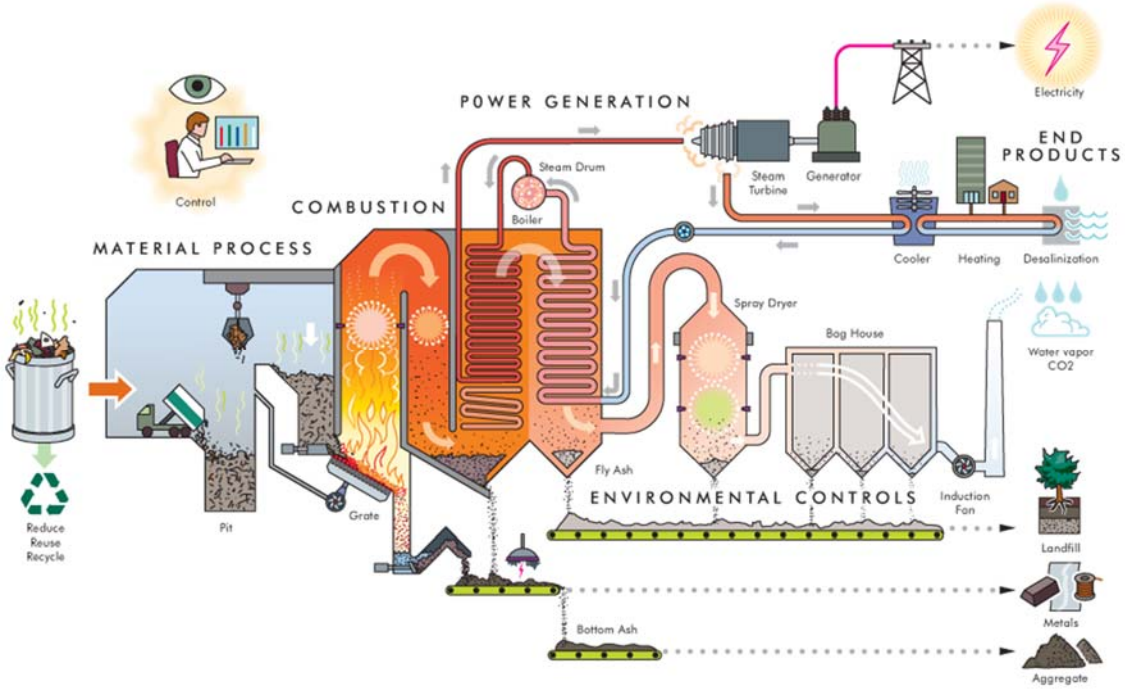

Figure 14: Waste-to-Energy Flow Diagram. Data Source: "Municipal Solid Waste Systems." Logic Energy USA. Web.

Unlike the transfer station, residents are not allowed to come and dump onto the tipping floor. It is left for commercial trucks. First, the trucks go on scales similar to a transfer station and get weighed, when they leave they exit through the same scale house to measure how much waste they delivered (“Covanta EfW Tour.”). At the scale, the waste is scanned for radiation to protect their plant’s process (“Covanta EfW Tour.”). After the scale house, the trucks go inside to a tipping floor (“Covanta EfW Tour.”). The

waste is unloaded and inspected for any unacceptable items, which are removed before the waste is pushed into a large concrete pit (“Covanta EfW Tour.”). The tipping hall and pit are kept under negative pressure to contain any dust or odors that the waste generates (“Covanta EfW Tour.”). Now the waste is being processed to become fuel. Once in the storage pit, which extends several feet underground to allow thousands of tons of storage, an operator with a giant grapple machine mixes the waste to create a homogenous mixture to keep the combustion even, then the waste is loaded into smaller hoppers that lead to the combustion chamber (“Covanta EfW Tour.”). Covanta burns their waste at about 2,000 degrees Fahrenheit, and the feed table that the waste enters in on keeps the material even ensuring continuous combustion (“Covanta EfW Tour.”).

At this point the process splits into three separate directions: the heat that creates steam for electricity generation, the gas and smoke that needs to be cleaned, and the ash and remaining leftovers of the waste. First the combustion process creates a large amount of heat that is pushed beside several feet of water in steel tubes thereby creating steam (“Covanta EfW Tour.”). In most cases, the steam is then piped to a steam turbine generator to create electricity, but for Covanta Huntsville they pump the steam to the Redstone Arsenal for their heating and air conditioning ventilation. Any excess steam from the process is condensed into water on-site and recycled back into the process called a “closed loop” system (“Covanta EfW Tour.”).

Second, the excess air and smoke goes through several cleaning processes before being released into the atmosphere. Covanta has a continuous emissions monitoring system that automates the combustion controls and tests the cleaning abilities of the air

pollution systems (“Covanta EfW Tour.”). First the smoke or flue gas is injected with lime and activated carbon to control any acidic gases or heavy metals in it (“Covanta EfW Tour.”). Then the air goes through a baghouse, which is a system that employs thousands of fabric filters to capture any particulate matter that remained in the air (“Covanta EfW Tour.”). The final system is nitrogen oxide monitors similar to that on a fossil fuel plant (“Covanta EfW Tour.”). The plant is under constant internal monitoring to ensure that the air meets the pollution standards before it is released and give the operators the ability to respond if there is a problem.

The third byproduct is the waste itself. At this point the waste is about 10% of the original volume (“Covanta EfW Tour.”). All of the waste material that comes out of the air pollution systems also get combined into this ash ("Waste-to-Energy …”). After combustion, any metal material still present is recyclable unlike the other waste that will go to a landfill. Covanta has two processes where it employs a drum magnet and eddy current to remove ferrous metal (steel and iron) and nonferrous metal (aluminum and copper) from the ash on a conveyor system (“Covanta EfW Tour.”). Even waste-to-energy leads to a landfill, though in only 10% of the previous waste volume significantly lengthening the life of any landfill. At this point, humans do not have a solution that will prevent the use of some form of landfills.

A key part to using waste for energy is its relative energy content or calorific value (Marshall). A rule of thumb is that a waste-to-energy incinerator should not be considered unless the incoming waste stream has an average calorific value of 7 MJ/kg because this ensures that the combustion process is self-sustaining (Marshall).

Fraction	Net Calorific Value (MJ/kg)
Paper	16
Organic material	4
Plastics	35
Glass	0
Metals	0
Textiles	19
Other materials	11

Source: ISWA (2013)

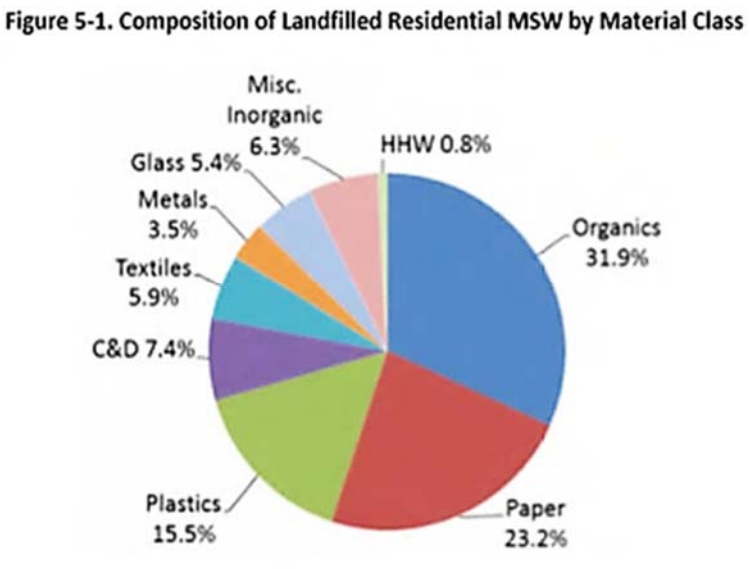

Table Data Source: Marshall, James, et al.
Figure 15: MSW Composition for Rutherford County and Approximate Net Calorific Value. Data Source: CDM Smith. Nashville Waste and Recycle Characterization Study Final.

The closest estimate for determining Rutherford County's Municipal Solid Waste (MSW) mix is Nashville's Waste Study shown in Figure 15. With this MSW mix, the average calorific value would be about 13.14 MJ/kg. This means that the relative MSW mix is a viable option for a waste-to-energy facility. The World Energy Council cites that the annual tonnage needs to be at least 100,000 tons for optimal operation of the plant (Marshall). However, the Solid Waste Directors stated that 300,000 tons of waste is required annually for proper economies of scale. Additionally, for waste-to-energy to work well, the organics or moisture content needs to be relatively small. This is in Rutherford County's benefit considering the portion of waste that is organic has decreased as the County becomes more urbanized. Compared to natural gas, which is very popular and cheap in the local area, waste calorific value is only 3.5 – 5 MJ/kg

where natural gas is 36-50 MJ/kg. Waste is a very inefficient fuel source (Marshall). Its inefficiency can be very useful today because Rutherford County currently has more waste than demand for electricity. There is no demand or proper infrastructure for them to convert waste-to-energy and be able to use it, so an inefficient fuel source means they will need to use a large quantity of waste and only gain a little electricity.

With waste-to-energy, the problem for Rutherford County is that it creates a product, electricity or steam, but there is no one prepared to accept this in the area. TVA prices out any selling of electricity because they price it at the hydropower price which is historically low. As mentioned earlier, for now Rutherford County needs an inefficient waste-to-energy process until the infrastructure and demand can grow. A problem is the feat that waste-to-energy programs will perversely incentivize people to waste more. Though, they have found that countries with waste-to-energy facilities still have high recycling rates (Marshall). If the waste hierarchy is emphasized and focused on, then the community will be focused on reducing waste generation if they have a waste-to-energy plant or not (Marshall). This is encouraging news, that recycling and waste diversion can thrive in a waste-to-energy disposal situation. The average waste-to-energy tipping fee in the United States is $68 per ton (Marshall). The low cost of oil and gas make it more economical to drive the waste to a landfill than to spend the electricity burning the waste for little electricity back (Marshall). To create a waste-to-energy facility, Rutherford County would need to decide that the reduced dependence on landfills and increased social happiness would offset this increased price. One of the suggestions GBB made was forming the waste-to-energy facility as a regional solution rather than only Rutherford

County (Gershman). This would increase the economies of scale on the facility, and it would lower the tipping cost with the cost of the operations spread over more people.

Environmentally, the plant does require water for cooling and to generate steam, but this water does not have to be sanitary (Marshall). Reused water could be continually recycled for this, lowering the plants' overall water consumption. Covanta already maintains a closed loop system for their water supply, reducing the amount of water that they discharge. The water that is discharged eventually will be contaminated with chloride and heavy metals, which will require it to be cleaned (Marshall). Waste-to-energy can result in greenhouse gas mitigation contrary to what many people believe (Marshall). The previously landfilled waste goes on to release methane and carbon dioxide into the air but is captured in this system (Marshall). As the plant begins to produce more energy, it will take away from fossil fuel generated electricity (Marshall). It can be considered as a green energy by the Tennessee Valley Authority, though this is an agreement that must be made with TVA before the construction of the facility. Since metals do not burn, they can be recaptured after the waste is burned and can reduce the amount that is mined, and the plant can reduce the cost of operations by receiving some revenue from the metal re-sale. At the actual incineration of the MSW, it produces 1,355.33 G/kwh of carbon dioxide where coal produces 1,020.13, but coal has additional emissions during mining and transport that is not considered (Marshall). This number is slightly misleading because it does not include how much carbon dioxide is prevented by the waste being incinerated instead of sitting in the landfill off-gassing carbon dioxide and methane for years to come. Gasification and pyrolysis are more advanced versions of

incineration that produce no carbon dioxide (Marshall). Research is being developed in the biochemical and chemical options to reduce air emissions (Marshall). Incineration is not the solution, but it is a successful form of technology that is favorable on land use, social aspects, and water quality.

Socially, when people see a smoke stack they immediately relate it to pollution and smog. This bias will be a big problem that Rutherford County would need to confront and discuss with their citizens. Waste-to-energy facilities do not have odor or litter problems like landfills and transfer stations do, so the effect on their neighbors' quality of life should be relatively minimized. The land space that an operation like this requires is approximately 30 acres, and in today's market this would be hard to find in a good, central location. No alternative will be the perfect solution, but Rutherford County must compare the relative strengths and weaknesses of each alternative to see what the combined solution will be.

Expanding Middle Point:

GBB's third suggestion is to expand Middle Point, allowing for more time to consider Rutherford County's next step and clean up the liability of the old Rutherford County landfill. Expanding Middle Point would include Republic Services taking ownership of both of Rutherford County's landfills, Class I and Class III/IV. The preliminary discussions agreed the County's landfill and Middle Point would be combined, and a recycling facility would be located at Middle Point as well (Gershman). This option is contingent on Republic Services being able to mine the old Class I landfill and see what material they are adopting. As part of the option, they agreed to remove the

waste from the old Rutherford County to a new lined cell, thus freeing themselves to add waste to that area and the valley in between the two landfills today (Gershman). The valley between the two landfills holds approximately 1.5 million cubic yards of air space available to fill (Nolen, Smith). With a landfill, the value is in the air space, so this space availability will increase Middle Point's useful life. This would extend Middle Point's life up to 25 years from now (Gershman).

Rutherford County benefits from this option because Republic Services would take sole responsibility for the old County landfill including the post-closure management and liability. There is no record of any environmental assessment that says any of the waste in the old County landfill is dangerous (Nolen, Smith). Plus, mining the landfill may be a lucrative option. For example, Lamar County mined its old landfill in order to install a pyrolysis plant and found that 70% of the volume was dirt or recyclable (Nolen, Smith). Also, five years after the old landfill was mined, the groundwater quality returned to a state cleaner than it had since the landfill was opened because the old landfill was unlined (Nolen, Smith).

The old county landfill would not be a cause for concern as it is today, if it sat in a lined cell. Though the entire landfill would still need post-closure care, the environment and groundwater would be more protected than it is today. The operations of an expanded landfill would be similar to how it is functioning today, though the environmental concerns would be prolonged. The water and air emissions would still need to be monitored and leachate collected. One possibility is that if Middle Point gets an influx of

waste, then Republic Services' landfill gas collection and cleaning systems might function better compared to them simply burning the landfill gas today.

However, the surrounding neighbors of the landfill have been repeatedly vocal in saying they do not want any expansion of the landfill. The landfill causes many noise, odor, and litter problems that the surrounding citizens are refusing to handle anymore. Socially, expansion of Middle Point would be very damaging.

Comparison:

Table 3: Waste-Baseline Cost Analysis

	Transfer Stations		Waste to Energy		Expand Middle Point	
Year	System wide cost increase	$/HH/Mo	System wide cost increase	$/HH/Mo	System wide cost increase	$/HH/Mo
2018	773,279	0.34	773,279	0.34	(325,774)	(0.14)
2019	1,746	-	1,746	-	(313,971)	(0.14)
2020	52,350	0.03	52,350	0.03	1,082,573	0.46
2021	75,392	0.03	75,392	0.03	1,129,212	0.48
2022	99,248	0.04	99,248	0.04	1,209,057	0.49
2023	123,942	0.05	1,602,719	0.65	1,873,600	0.76
2024	149,498	0.07	1,678,494	0.67	2,007,331	0.80
2025	175,943	0.07	1,756,881	0.69	3,914,358	1.53
2026	203,304	0.08	1,837,968	0.71	4,093,539	1.58
2027	16,247,323	6.14	41,037,213	15.49	4,322,639	1.63

(HH means household) Data Source: GBB Final Draft Analysis

Table 3 shows Rutherford County's relative costs for these three alternatives. The dramatic reduction in year 2019 is from the closure of Rutherford County's Class III/IV landfill. The operation costs are complete, and only post-closure care costs are felt. Between these three options GBB gave Rutherford County, the amount of technology required is different which directly affects the price and cost to operate. There are more

options to consider as alternatives. This is deciding the baseline from which to compare other alternatives.

First, transfer stations require a lot of infrastructure to be built, but the technology is not sophisticated, it can adapt into many different uses. Expanding Middle Point requires the least amount of technology because Republic Services takes the responsibility of renovating the landfills and any future responsibility of the landfills. Waste-to-Energy is a technology-heavy investment that requires ten years to build. This requires changing infrastructure and building a facility capable of collecting the waste, converting the waste, and distributing the energy created.

Expanding Middle Point is the least economically expensive and improves the environmental situation of Rutherford County's old landfill, but socially it is the most universally hated option. As transfer stations are closest in price to the Middle Point expansion, require a minimal amount of land alteration, and have public support, transfer stations are the best baseline for Rutherford County's current situation. Waste-to-energy is a riskier baseline which does not match what Rutherford County is currently researching. To use waste-to-energy as the baseline, the comparable alternatives would be more technology-intensive projects like the chemical waste-to-energy concepts or other experimental options. Rutherford County seems to be trying to stay at the same amount of risk as a landfill, so the best comparison option are the transfer stations. If the conversation ever shifts to include more advanced waste disposal options, then the baseline can be shifted to waste-to-energy. This is a similar situation to world cellphone adoption. In America, the first step was a landline that required a lot of infrastructure.

However, Africa's first step was cellphones. They skipped the intense infrastructure phase because the newer technology applied better to their needs. There is not an exact timeline and evolution of waste technology that Rutherford County must follow, but the choice should be studied to decide what Rutherford County will do.

Ways to Reduce Waste Generation:

Public education and understanding of the waste situation are large problems that Rutherford County faces today. However, moving forward, the public is going to be required in decisions and in reducing overall waste generation for the betterment of the environment.

Public Education:

One of the main solutions to waste is prevention. A popular concept around this theory is the circular economy. This is a movement to shift humans from the existing linear economy–where things are extracted from the ground, go into production, sold to the consumer, and then thrown away. The circular economy takes all of these waste streams and turns them into products or material in profitable streams. Nature is based on a system of feedbacks and circularity, and the circular model is based on mimicking nature and rebuilding the system's health. The circular economy designs out waste and pollution, keeps materials in use, and regenerates natural systems both globally and locally.

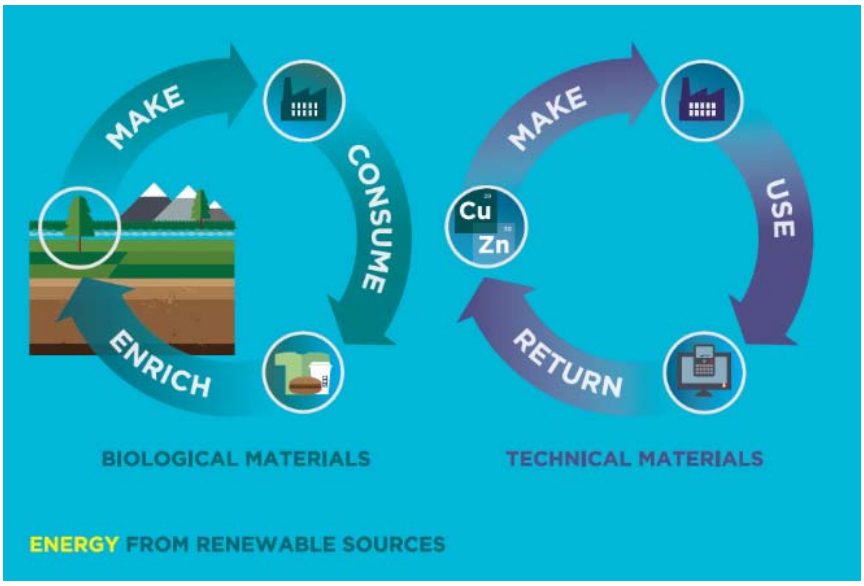

Figure 16: The Two Cycles from the Circular Economy. Data Sources: "Two Cycles." *Ellen MacArthur Foundation.* Web.

There are two types of cycles that the circular model addresses according to the Ellen Macarthur foundation, technical and biological (“Two Cycles”). Biological cycles are materials such as food or wood that are consumed and fed back into the system through composting or an anaerobic digester (“What is a circular economy?”). “Technical cycles recover and restore products, components, and materials through strategies like reuse, repair, remanufacture, or (in the last resort) recycling” ("Building Blocks."). Materials in the technical cycles are not a part of the living system. More creative solutions must be used for finding alternative solutions instead of landfill. The circular economy does not focus on how to sustain the current ways of completing things, but changing how we do everything to achieve sustainability and keep these industries running (“Who’s leading …”).

The circular economy is a mindset switch that comes with significant switching costs. Instead of planning for products and services to be disposable, the manufacturer's plan becomes more technical and in depth to return the products into the system or make it become part of the biological lifecycle. The circular economy adjusts traditional economy thinking from turning nature into mechanical to turning industry and mechanical aspects into the biological cycle.

The four building blocks businesses need to transition towards the circular economy is circular economy design, new business models, reverse cycles, and enablers and favorable system conditions. *Circular economy designs* include companies building core competencies into their business to facilitate product reuse and recycling ("Building Blocks."). *New business models* simply include innovative businesses either existing or new ("Building Blocks."). Companies with vertical integration can force the economy to follow their lead more easily than horizontally integrated companies that have other companies to answer to ("Building Blocks."). *Reverse cycles* are additional skills to return materials to the land or another production system ("Building Blocks."). These *favorable conditions* include popular recycling market or support from educators and policy makers. ("Building Blocks."). The first three building blocks focus on the business and how it pushes towards this economy, but the fourth building block depends almost solely on public opinion. If the public does not support this revolution, no amount of material processing innovation will be able to push the circular economy forward.

Waste diversion is another integral part of the circular economy because it views waste as a multi-value commodity. Currently landfills' only commodity is the airspace

inside it. If a waste plan can include all of these multiple steps then the waste is valued for its material, quantity, and quality.

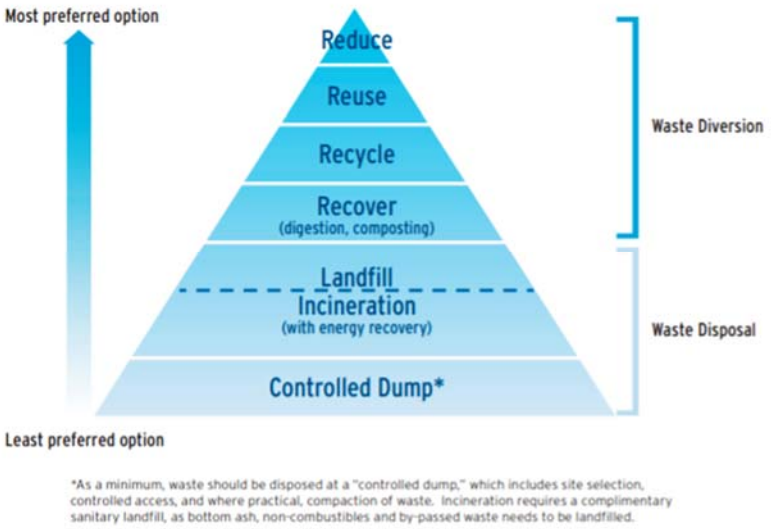

Figure 17: The Hierarchy of Waste Diversion methods to Waste Disposal. Data Source: Hoornweg, Daniel, and Perinaz Bhada-Tata. What a Waste: A Global Review of Solid Waste Management. Washington DC: World Bank, 2012. Print.

Figure 17 describes the idea of the most preferred option to least preferred regarding the products we use and diverting it from the landfill. Waste diversion is defined as methods of diverting waste away from a landfill specifically. First, reducing purchases or packaging in the first place is the best option of preventing anything from going to the landfill. This is based on individual's choices, such as a person at a store deciding on what to purchase. Producers can also be included in reducing by reducing their packaging to the bare minimum. For example, a box of cookies does not need to be wrapped in two bags of plastic and a cardboard box. One plastic wrapping or loosely

placed in the cardboard box is enough to ensure safe travelling and prevent any harmful vectors from getting inside. This example is also known as product stewardship.

Second, reuse can be classified as any action that reuses the original product in its same shape, where the only processing that is required is possibly washing (Hoornweg). For example, there are some stores that buy their products in bulk containers and encourage their customers to bring their own glass or plastic containers to refill with the products they want, rather than buying a brand-new bottle. This works well with personal care products like shampoo, soap, lotion, or cooking materials like flour, sugar, and spices.

The third waste diversion technique is recycling. This is when the original product is cleaned of contamination and returned to be processed into virgin material or into other marketable products. For example, glass is often recycled and is melted back into virgin material that can be re-molded for another glass or jar. The main problem with recycling is contamination. Contamination is an ill-defined word that applies to everything from a lightbulb in the glass recycling container to leftover food and liquid in the plastic and aluminum cans. Contamination is a major problem that recyclers and second market buyers are facing today because the cost to wash these products often make it unprofitable compared to buying the virgin material. Recycling is often seen as the last effort by environmentalists though this seems to be the only waste diversion concept the public knows and discusses.

The final type of waste diversion is recovery. Recovery is when the material is recovered for its biological use. This includes digestion and composting (Hoornweg).

These alternatives use the material and regain some of its benefit as a biological organism. The waste is often sorted between recovery and recycling to make these processes more efficient. Any plastics or other inorganics should be diverted at the recycling stage where the organics and food waste can be recovered for composting in the second stage.

Now incineration or waste-to-energy plants are another form of waste disposal, instead of taking up air space we use the waste for its BTU value. Energy recovery can be very lucrative in a high electricity price area. For Tennessee, the electricity price is set at a low price because of the Tennessee Valley Authority Act. It is not beneficial for Rutherford County to use the waste to generate electricity, even though it is an alternative energy source. One aside for incineration is creating steam for heating and ventilation. Nashville's old incinerator used to create steam for the downtown area, but it was not always compliant with its air pollution standards. Still incineration is seen as more beneficial than landfills that act as giant storage tanks.

One of the more actionable concepts of the circular economy is product stewardship. This is when the responsibility of the waste stream is put on the producer of the product. For example, paint is a harmful waste stream because of its toxicity and the often mismanagement of its disposal. Product stewardship puts the responsibility of proper disposal to the paint sellers which have caused some to create take-back programs for the customers to return the extra paint and the can to be disposed of, turned into new material, and recycle the containers. There are companies beginning to specialize in advising companies on their waste streams and product stewardship. For example, New

Zealand has several nationwide product stewardship programs including tires, paint, agriculture chemicals, and waste oil lubricant containers.

In New Zealand, environmental stewardship is held at a forefront for the consumers and the businesses. Though GBB says that source reduction only leads to a 2-3% impact on diversion (Gershman). Seeing the effect on people's attention and business's innovation made a visual impact that is not often felt with other recycling programs. Recycling and minimizing waste are part of their daily routine. Especially highlighted was the popularity of composting everywhere. Not only did all houses and businesses have their own recycling organizers at their house, but they also had their own composting either for their chicken feed, worm garden for fertilizer, or collected curbside for the composting plant. At gas stations and other public businesses, recycling and waste diversion was set equal to landfilling as seen in Plate 4.

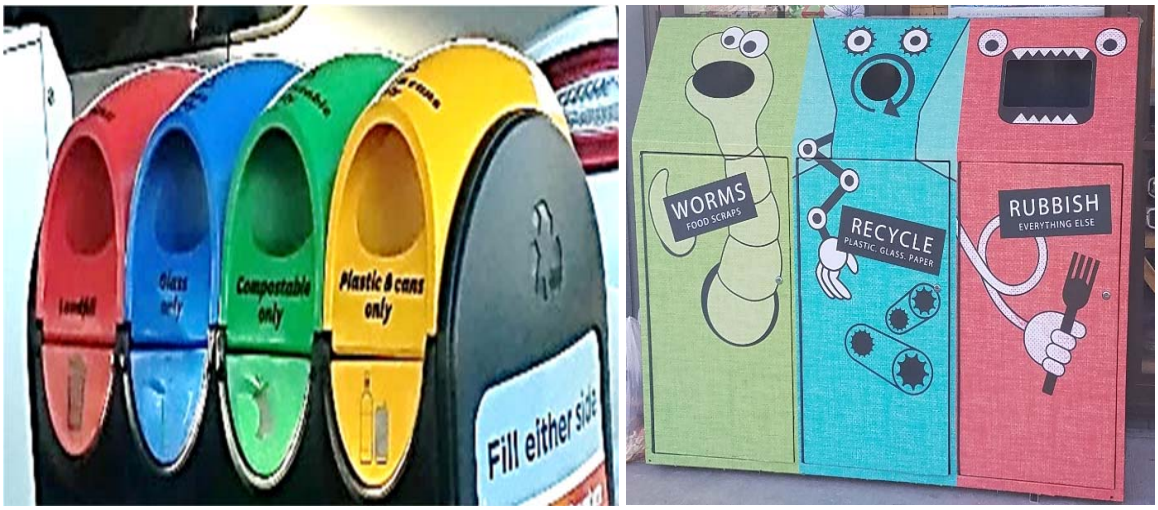

Plate 4: Pictures of Public Waste Bins in New Zealand (on the left is from a gas station, on the right is from outside of a convenience store)

Since the waste mix is very different between New Zealand and the United States, the solution is not to put composting on every corner. However, public opinion and education is a highly important topic and should be put first on any integrated solid waste plan. The problems in Rutherford County have been aggravated because solid waste is hidden. Though everyone wants it taken care of, no one wants it near them. New Zealand embraces solid waste management as part of their life and knows that waste needs to be minimized for the sake of future generations. Their local governments currently hold public meetings to hear tenants' complaints about garbage, and their complaints were not about the smell though a few were about the price. The people who spoke at the meetings want waste to be taken care of responsibly and minimized as much as they can reduce. The government has installed a version of Pay-As-You-Throw programs by giving out smaller bins to incentivize people to reduce their consumption patterns, or they will have to pay more for extra garbage bags from the grocery store.

Eventually waste needs to be treated as a utility. For electricity, the customer only pays for the amount that used plus a convenience fee. Waste should be treated the same way with a "pay-as-you-throw" (PAYT) program. When trash service is paid through property taxes, then the user never has a complete understanding of what they are paying for. Property taxes are used to pay for many different fees that are difficult to differentiate and ends up appearing "free" (WasteZero). Rutherford County has had free waste disposal for years, the payment should not be buried in property taxes. The citizens are not incentivized to reduce their waste (WasteZero). With PAYT systems the residents are charged for how much trash they generate, which makes for a fairer system in the whole

(WasteZero). When people see that how much waste they generate has a direct impact on how much they are charged, it will change how they view waste. There are three popular types of PAYT systems: bag-based where residents use an official city bag, sticker based where residents can use any bags they want but have a pre-paid sticker attached like a stamp, and variable rate cart system where citizens choose what size cart they want and are charged accordingly (WasteZero). Overall it seems that the bag-based system creates the least pounds per capita ("Results."). A PAYT program focuses people's attention on waste and incentivizes reduction. People can support PAYT when they see that they are paying the same price producing one garbage bag a week as a family that is producing four garbage bags (WasteZero). People instinctively want fair paying schemes. With a PAYT program, the responsibility of waste generation is directed at the consumer instead of being solely based on material costs. As this begins to happen, then the people will begin to demand that companies do better and give them products with less disposable packaging. It will incentivize recycling, waste avoidance programs, and show people how much it really costs to waste. Public education and changing people's opinion about waste is the solution. Rutherford County needs innovative ideas on how to spread this message and educate more citizens (Nolen, Smith).

Conclusion:

Solid waste is a deceivingly complex issue where people are currently facing a tipping point. If we continue burying waste and generating more, we will start a cycle that cannot be slowed down. As more waste is generated, more land is destroyed for raw materials, and as more waste goes into landfills, more potentially dangerous air and water

pollution is created. Even though waste problems continue to grow today and continue to be willfully ignored, waste is one of the easiest environmental problems to solve. Compared to replacing fossil fuels, providing fresh water to the entire world, or stop desertification of former croplands, reducing waste generation seems achievable by an average person. Waste is not an extraordinary problem, we have been treating it wrong for all these years. Solid waste is a utility that we need to recognize instead of dismissing. Because of our mindset about waste, any individual solutions are treated as a luxury instead of the necessity it is to our life. Proper waste disposal is necessary for our health and safety as a society, but people and politicians willfully choose to ignore its existence.

Focusing on Rutherford County, the current disposal option has been a peculiar situation. However, the previous contracts with Republic Services and free disposal are sunk costs literally and figuratively. There is not another situation where Rutherford County will have a landfill near Murfreesboro City that provides the residents with free waste disposal and relatively free waste collection depending on if they use the convenience centers or private haulers. When deciding on what to do in the future, this option should not be used as a baseline. The transfer stations should be considered as the baseline for any comparison to other options because it estimates the costs of the safest and most reasonable waste disposal choice. Rutherford County and the municipalities (Murfreesboro, Eagleville, Lavergne, and Smyrna) need to decide on their next step within a year from now because all the options they are considering require a long time to build and raise money to afford. The first step is to complete an Integrated Solid Waste Assessment Plan. As they are researching alternative options, one could come that does

not require transfer stations and provide solution for all of Rutherford County's waste then that technology can be built. Transfer stations are not the solution to Rutherford County's waste problem, but it is what solutions should be compared against.

This is Rutherford County's opportunity to innovate and invest in a new technology that is "zero landfill." Many of these waste technologies require a large amount of tonnage to make the economies of scale reasonable. Rutherford County produces 350,000 tons annually today and is expected to produce 458,000 tons in 2027 when Middle Point closes. Investing in a technology, where it only encourages people to waste more, for those economies of scale seems perverse to me. Rutherford County should continue to work with the other counties that already have the infrastructure to send their waste out-of-county and have a regional solution to everyone's waste. This one solution will create incentives for people to waste less because if they continue to increase their waste then this solution will run out of life and increasingly cost more.

Similarly, between composting and recycling, public education and responsibility seem to be a fundamental problem that continues to limit Rutherford County's options. In the waste industry, the citizens who produce the waste have a willfulness to ignore the whole situation and the waste companies only share limited amounts of information. There is a vicious cycle between citizens not wanting to know what happens to their waste after they place it in the bin and waste companies happy to disappear into the background. However, this has created an air of mystery and conspiracy around the waste companies. People do not trust waste companies because they do not understand what happens. Any possible solution needs to be discussed with the community and keep them

informed about the current waste situation. It is a complex problem without a one-size solution, and if the public understood these problems then they could help or at least appreciate being heard and consulted. Public education is solid waste's primary problem because there is no easy way to get the information to everyone involved (Nolen, Smith). Considering social media, not everyone has a computer or follows the Rutherford County account, mail options are often just discarded, and public meetings have limited resident involvement.

Rutherford County should invest in a 100 – 200-acre industrial park that gives them enough space to run multiple waste operations (Nolen, Smith). The waste could be moved throughout all of the facilities with negligible transportation costs once at the park. Despite the solution, there is no 100% zero waste option. At this industrial park, there will be a space designated for landfill, but the plan is that all of the solutions chosen combine to limit the amount of waste landfilled considerably. Before Rutherford County can decide on a solution, a study needs to be done on Rutherford County to discover what their waste generation composition is. More focus should be put on waste generation. Especially in the context of a regional solution, responsibility should be put on the producers and the citizens. Regionally, the governments could demand more producer responsibility and stores and products that have less wasteful packaging. For example, Kroger is banning its own plastic bags and taking responsibility for limiting the amount of plastic it puts into the economy. At least Rutherford County should put a Pay-As-You-Throw program in place to make residents aware of how much they waste. PAYT programs can decrease the amount of waste generated and create more pressure for

business and industry to respond to this change. In today's environment, it is costlier for Rutherford County residents to be environmentally conscious and responsible. People generally know what is best for the environment. It is up to the government and businesses to provide those options at a feasible cost. Together, Rutherford County, the municipalities, the citizens, and the businesses need to find a solution that is mutually beneficial for each other and the environment. Other states and countries have found ways to reduce waste. It is not impossible, but it does require everyone's participation and education.

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Appendix A: Definitions

- Borrow Pit – an excavated area where material has been dug for use as fill at another location. The landfill has made contracts with borrow pits across the County.
- Browning Ferris Industries (BFI) – the original buyer of Middle Point landfill. They were purchased by Republic Services.
- Class I disposal facility – takes non-hazardous municipal solid wastes (household wastes, approved special wastes, and commercial wastes).
- Class II disposal facility – takes non-hazardous industrial wastes, commercial wastes, and fill.
- Class III disposal facility – takes Class IV wastes plus landscaping, land clearing, and farming wastes.
- Class IV disposal facility – takes construction/ demolition wastes, shredded tires, and waste with similar characteristics.
- Contamination – any trash waste or unaccepted material that is mixed with the recyclables
- Convenience Center – a centrally located collection point for the temporary storage of waste for individuals to use instead of taking directly to a disposal facility. Rutherford County recently re-named to recycling center.
- Daily Cover – the material and act of covering the day's disposed waste in a landfill cell at the end of the operating day to control odors, fire, vectors, litter, and scavenging. Traditionally uses soils, but alternative cover can be approved.

- The Environmental Protection Agency (EPA) – a federal agency created in 1970 to protect human health and the environment by writing and enforcing regulations.
- Eweson digesters – a forced decomposition process in composting. The digester is a large cylinder that rotates the material and raises the temperature to 160 degrees Fahrenheit to sterilize it. The waste stays in the digester for 3 days to be rated as inert.
- High-density polyethylene (HDPE) – type 2 plastic resin that usually makes milk jugs and detergent containers.
- Landfill Gas – a natural byproduct of organic waste anaerobically decomposing at landfill sites. Approximately 50% methane and 50% carbon dioxide.
- Landfill Gas Collection Systems – the collection system put in place to capture the landfill gas involves long boreholes with perforated pipes and a suction loop to collect all the gas to the surface either to be vented, burned, or treated for biofuel.
- Leachate – a natural byproduct of waste decomposing and is any liquid that forms when water passes through solid waste. Has a tendency of carrying suspended particles and chemicals from the waste to the local groundwater. Must be collected and monitored.
- Material Recovery Facility (MRF) – an intermediate processing facility that accepts recyclables and processes them for wholesale distribution.

- Municipal Solid Waste (MSW) – waste material from households and businesses, not regulated as hazardous including residential, commercial, and institutional wastes
- Not-In-My-Backyard (NIMBY) – an expression of opposition for a waste facility's siting near a community. An expression for people's state of mind considering waste disposal.
- Optical Sorter – specialized machinery placed in a manufacturing facility that uses video sensors and color to recognize a specific type of material. Used in material recovery facilities.
- Organics – an object derived from living organisms and can decompose
- Pay-As-You-Throw (PAYT) – a variable rate, waste collection program that promotes waste reduction by charging for waste disposal based on the weight or volume of the material.
- Polyvinyl chloride (PVC) – a clear plastic that can be stretched but is very durable. Off-gases dangerous chemicals when burned.
- Tennessee Department of Environment and Conservation (TDEC) – A department set up to manage environmental and public health in Tennessee.
- Tipping Fee – the price set by the landfill owner to allow individuals, communities, and trash haulers to dispose of waste at a landfill.
- Tipping Floor – the first location at many waste disposal sites that allows trucks to tip the waste out onto the floor. Inspection of waste occurs on the tipping floor before the waste enters the disposal process.

- Transfer Station – a facility where waste is collected from smaller vehicles to load onto larger transport vehicles.
- Triple Bottom Line – an assessment method that equate the environmental quality, social quality, and economic value.
- Vector – any agent (person, animal, or microorganism) that carries or transmits an infectious pathogen to another living organism.
- Waste Diversion – the sum of recycled, composted, and donated or reused materials that result in the waste not going to a landfill. Waste diversion is also the category of any action that reduces the amount of waste going to landfill.
- Waste Generation – the weight or volume of materials that enter the waste stream before recycling, composting, landfilling, or combustion. The amount of waste generated by a given source or sources.
- Waste-to-energy – a facility where municipal solid waste is converted into a usable form of energy (steam or electricity) usually by combustion.
- Zero Waste Community – a goal to guide people to emulate sustainable natural cycles where all discarded materials are resources for others to use. A strategic goal that guides all design and management decisions.

Appendix B: TDEC Annual Progress Report – Sector Summary Report

Data Source: TDEC Annual Progress Report

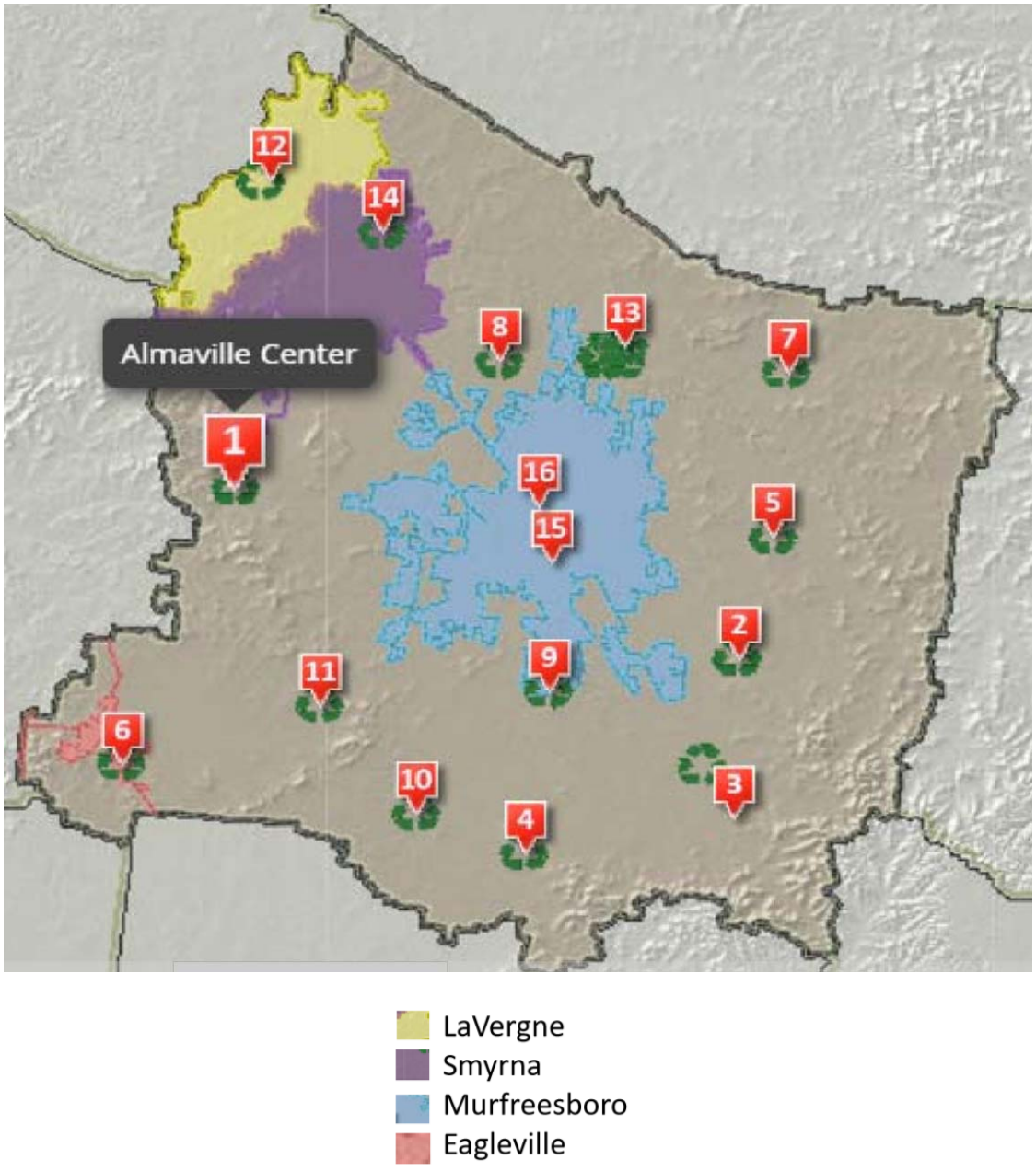
TN Department of Environment & Conservation

Tennessee Sector Summary Report

Timeframe: 2017 to 2017, Organization: Rutherford APR

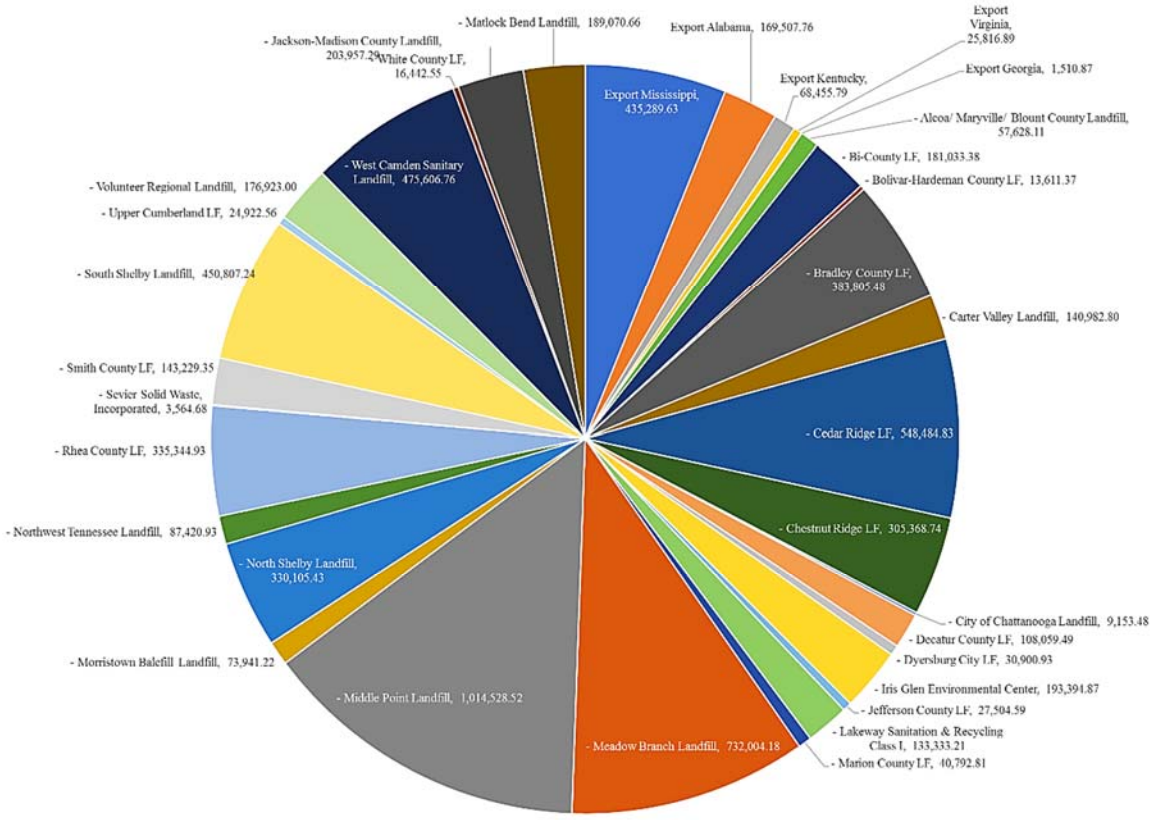
Type	Residential	Commercial	Institutional	Industrial	Commercial, Industrial	Commercial, Institutional	Commercial, Industrial, Institutio	All Sectors	Special Event	Other	Total Tons
Sectors											
Recycling	19,495.52	28,497.74	758.22	232,421.40	-	-	-	-	0.52	62.48	281,235.88
Waste Diversion	38,790.00	1,200.08	1.00	20,401.80	-	-	-	-	-	-	60,392.88
Hazardous Waste	9.92	-	-	-	-	-	-	-	-	-	9.92
Solid Waste	384,010.39	-	-	-	-	-	-	-	-	-	384,010.39
Total	**442,305.83**	**29,697.82**	**759.22**	**252,823.20**	**-**	**-**	**-**	**-**	**0.52**	**62.48**	**725,649.07**

Appendix C: Map of Rutherford County Convenience Centers and Landfills



Data Source: Gershman, Brickner, and Bratton

Appendix D: Tennesse Total Class 1 Landfills



Data Source: TDEC Annual Progress Report