Bristol, VA: A Sustainable Recycling Strategy

By Sheila Joyce

Applied Policy Project

Frank Batten School of Leadership and Public Policy

Prepared for Bristol, Virginia

Table of Contents

Key Terms and Acronyms

MRF – Materials Recovery Facility

GHG – Greenhouse Gas

EPA – Environmental Protection Agency

DEQ – Department of Environmental Quality

Landfill – A site for disposal of waste materials by burying it and covering it with soil

Contamination – The presence of non-recyclable materials in the recycling stream which can reduce the value of marketability of collected recyclables.

Mandatory Disclaimer

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other agency.

Executive Summary

Bristol, Virginia, faces significant challenges due to its nearly non-existent recycling rate, which fails to meet the state's mandated 25% recycling rate. This technical report aims to provide actionable recommendations to address this issue, improve the city's recycling infrastructure, and enhance the quality of life for its residents.

The citizens have no adequate recycling options and currently have a recycling rate close to 0%, which is far below the state's 25% mandate. Failure to meet this requirement could result in severe financial penalties and loss of state funding, exacerbating the city's existing economic struggles.

Recycling in the United States has been significantly impacted by China's National Sword policy, which restricted the importation of recyclable materials. This has led to increased costs and decreased revenue for recycling programs nationwide. Virginia's legal regulatory environment mandates a 25% recycling rate, which Bristol has failed to meet since 2019. Bristol, a city of approximately 18,000 residents, has suffered economic setbacks including substantial debt and the closure of local landfills, which further complicates the issue.

If Bristol does not meet the state's recycling mandate, it could face financial penalties of up to $250,00 annually. The city would also become increasingly reliant on landfills which leads to higher operational costs and negative environmental impacts, including greenhouse gas emissions (GHG), depletion of natural resources, and air pollution.

An evidence review identified three key strategies for increasing Bristol recycling rate:

1. Recycling Infrastructure: Implementing single-stream or multiple-stream recycling systems.
2. Reducing Landfill Waste: Composting to eliminate food waste.
3. Citizen Participation and Support: Engaging citizens through educational campaigns and nudges.

The technical report evaluates two tiers of policy alternatives:

Tier 1: Infrastructure

A. Single-Stream Recycling Systems: Simplifies sorting and exceeds 25% mandate but is more expensive.
B. Multi-Stream Recycling Systems: Increases the quality of recyclables at a lower cost but does not meet the 25% mandate.

Tier 2: Supporting Strategies

C. Public Education Campaign: Increases awareness and participation through generated materials but does not adequately improve the recycling rate.
D. Household Composting Program: Encourages citizens to compost food waste and reduce landfill contributions which adequately improves the recycling rate.

The alternatives are evaluated based on their estimated effectiveness in increasing the recycling rate, cost, cost-effectiveness, environmental stewardship, and political feasibility.

This report recommends implementing a **single-stream recycling system** supported by a **household composting program** to yield a total improvement of approximately **46%** recycling rate. Exceeding the 25% mandate is justified by long-term savings, environmental benefits, community engagement, economic opportunities, and risk mitigation.

To implement the recommended programs, Bristol must:

1. Implement the household composting program immediately
2. Select a suitable materials recovery facility (MRF)
3. Secure funding and design efficient collection routes
4. Conduct a pilot program to test single-stream recycling system
5. After pilot program success, implement single-stream recycling system city-wide
6. Continuously monitor and adjust the programs to ensure success

Implementing a single-stream recycling system and household composting program will help Bristol meet and exceed the state's recycling mandate, fostering environmental stewardship, community engagement, and long-term economic benefits for the city.

Acknowledgements and Dedication

I would like to express my sincere gratitude to Professor Alexander Bick and Professor Daniel Player for their invaluable guidance and support throughout the development of this report. Their expertise and insights were instrumental in shaping the direction and focus of this work. I am also deeply grateful to Tamyra Spradlin, Assistant City Manager of Bristol, Virginia, for providing the opportunity to address this critical issue and for her commitment to finding sustainable solutions for the city.

This policy brief is dedicated to the citizens of Bristol, Virginia whose well-being and environmental future are at the heart of this endeavor. It is my hope that this report will contribute to a more sustainable and prosperous future for generations to come.

Introduction

The escalating challenges presented by the lack of recycling options demand a comprehensive and strategic response. This technical report provides a rigorous analysis of this issue, examining its underlying causes, consequences, and potential solutions. Prepared for Bristol, Virginia, the purpose of this report is to develop actionable recommendations that are rooted in relevant evidence. It encompasses a detailed analysis of several different recycling strategies including single-stream systems, multiple-stream systems, and composting. Finally, this report presents a proposed model for implementation to ensure the effectiveness and sustainability of the proposed recommendations. Through evidence-based analysis, this technical report seeks to inform and empower Bristol in its commitment to meeting the recycling rate mandate and increasing the quality of life for its citizens.

Problem Statement

Suffering from the region's economic decline and increasing environmental regulations, **the citizens of Bristol have no adequate recycling options and are not meeting the state's 25% recycling rate mandate**.[1] If Bristol does not meet this requirement, the city may face severe financial penalties up to $250,000 and/or loss of state funding (U.S. Environmental Protection Agency, 2024). Since 2019, Bristol's recycling rate has been nearly 0% and there are no current measures in place to change this.

Client Overview

My client is Bristol, a city of approximately 18,000 located in southwest Virginia. The mission of the Bristol City Government is to provide quality services and ensure a safe, diverse community for its residents (Bristol, 2024). The Public Works department is reflective of this statement by providing each citizen with the opportunity to recycle and meet the state's environmental regulations. The department is responsible for managing the solid waste collection, disposal, and recycling services. The most important of these regulations mandates the city maintain a 25% recycling rate. If Bristol does not meet this requirement, the city may lose their $52 million state funding and suffer other severe financial penalties (U.S. Environmental Protection Agency, 2024). Public works is responsible for managing recycling centers, sorting the materials, and transporting them to a correcting waste management facility for processing (Bristol Public Works, 2024). Currently, there are only three operational centers and have been restricted to only accepting cardboard under a strict schedule. The most important of these regulations mandates the city maintain a 25% recycling rate, which they have failed to satisfy since 2019.

[1] The recycling rate is calculated by dividing the total amount of waste recycled and the total amount of waste generated.

Background

The purpose of this background section is to describe the history of recycling in the United States and describe how the national developments regarding recycling impact Bristol. This section will begin with a brief definition of recycling followed by an overview of the status of the recycling market in the U.S, including a discussion the impact of China's National Sword policy. It then discuss Virginia's legal and regulatory environment concerning recycling. This background will detail Virginia's 25% recycling rate mandate and the current state of Bristol's recycling program. It will conclude by giving an overview of Bristol's unique history and discussing the economic setbacks contributing to this issue.

Recycling in the United States

The Environmental Protection Agency (EPA) began collecting and reporting data on waste disposal and recycling in 1989. In 1960, the U.S. recycled or composted less than 7% of its waste. Since then, the recycling rate has increased by 457%. As of 2018, the EPA reported 23.6% of municipal waste in the U.S. was recycled and 8.5% was composted. 94% of Americans have at least one recycling program available to them (RubyHome, n.d.). However, the United States is recycling significantly less compared to other countries around the world. According to the Economic Policy Institute, the U.S. ranked 24th in recycling rates across countries with some sort of recycling programs in place. South Korea had the highest recycling rate globally with 56.5 percent. To address this issue, the EPA created a national recycling goal to increase the national recycling rate to 50% by 2030 (U.S. Environmental Protection Agency, 2024). States, including Virginia, created recycling rate mandates to help meet this goal.

While recycling processes often differ by the type of material and locality, there are three key steps: collection, processing, and remanufacturing. Recyclable materials are collected by either the government or private entity. Localities commonly collect materials using curbside collection, deposit systems, buy-back centers, and depots (Oregon State University, n.d.). Once transported to a processing facility, the materials are sorted, cleaned of contaminants, and prepared for transport to a milling facility or directly to a manufacturing facility. Some materials require more processing and decontamination than others, including glass and plastic (U.S. Environmental Protection Agency, n.d.). Once material is fully processed, they are remanufactured into new products are recycling plants or other facilities.

China's National Sword Policy

The ability to ship recyclables to foreign markets has played a pivotal role in the amount of recycling conducted nationally. The largest of these markets was China, accepting nearly 40% of the nation's total recyclables in 2016 and nearly half of the world's recyclable waste for the past quarter century (Virginia Department of Environmental Quality Report, 2019). However, the nation's recycling was significantly reduced due to China's National Sword policy. In 2017, to reduce smuggling and illicit activities related to recycling and waste materials, China implemented a policy that heavily restricted or banned the importation of most recyclable materials (Wahab & Lim, 2022). This created a major global shift in where and how materials are recycled and processed. The costs to collect recyclables increased significantly, renders the practice almost unprofitable (Katz, 2019). Across the globe, more recyclable materials are being

disposed of in landfills, incinerators, or littering the environment. Between 2017 and 2018, the U.S.'s recycling rate dropped from 64% to 35% nationally. China's policy left the U.S's recycling market extremely underdeveloped due to the increase in costs associated with recycling and a decreased in revenue associated with recycling (Katz, 2019). Recycling centers struggled to adapt to the changing market (Virginia Department of Quality Report, 2019). To avoid forced closure, many waste management providers were forced to increase their prices which were unaffordable to many communities including Bristol. All nearby waste management facilities Bristol had contracted for recycling had closed, leaving the city without a facility within a reasonable distance. China's National Sword policy is primarily responsible for the U.S.'s underdeveloped national recycling market, making it difficult for localities for Bristol to develop recycling initiatives.

Virginia's Legal and Regulatory Environment

Recycling in Virginia is composed of solid waste planning units (SWPU) which are cities, towns, and counties responsible for managing all recycling programs within the region. SWPUs must meet the state's solid waste planning and recycling requirements. Once the recyclables are collected, the materials are transported to a processing facility where it is collected, sorted, cleaned, and restored. Once the material has been processed, it is purchased by a producer in need of the material. In this process, Bristol is responsible for collecting citizen's recyclables, contracting a material processing center for processing, and transporting the materials to the center. All these components are necessary for Bristol to provide its citizens with recycling options. Due to a lack of recycling facilities nationwide, the cost of recyclable materials has significantly increased, and it is more affordable for producers to purchase new material instead. Therefore, the market demand for recycled materials is unable to address this problem.

Recycling in Virginia is managed by the state's Department of Environmental Quality (DEQ). The department manages a robust recycling infrastructure dependent on local government, citizens, and waste management facilities (Virginia Department of Environmental Quality, 2024). The U.S. Environmental Protection Agency (EPA) defines the recycling rate as the percentage of municipal solid waste this is recycled (U.S. Environmental Protection Agency, 2020). While the EPA provides a national framework for measuring recycling rates, states can implement their own methods and criteria for defining recycling. Virginia defines the recycling rate as the proportion of the total amount of recycled material in weight by the total amount of solid waste generated (Hotta, Visvanathan, & Kojima, 2016). In 1989, the Virginia General Assembly established a 25% recycling target rate for communities and tasked the Virginia DEQ with enforcing this regulation (Virginia Department of Environmental Quality Report, 2019). In addition to meeting this target rate, localities must also maintain an approved solid waste management plan and meet all Solid Waste Planning and Recycling codes (Virginia Department of Environmental Quality Report, 2019).

Bristol's lack of recycling options is a growing issue requiring immediate action. Bristol's economic struggles compounded with the national shortage in foreign exportation of recyclables has created a complicated web of policy implications. Bristol must meet Virginia's environmental mandate requiring the city to meet a 25% recycling rate in the next coming years to avoid losing their $52 million state funding and any other federal ramifications

History of Bristol

Bristol is an independent city located in southwestern Virginia with a population of 16,807 (U.S. Census Bureau, n.d.). The city is in a relatively isolated area, with the closest metropolitan area being Knoxville, TN (113 miles). As shown in Figure 1, the nearest recycling processing facility is in Roanoke, VA (149 mi.), which would take approximately five hours to complete a round trip. This distance is too far for trucks to cover daily.

Figure 1. Map of Virginia MRF Facilities

According to the 2020 census, the racial makeup of the city was 85.10% is white, 5.85% Black or African American, and approximately 9% from other races (U.S. Census Bureau, n.d.). This lack of racial diversity can lead to the underrepresentation of minority communities during the development of any policy intervention.

It is the twin city of Bristol, Tennessee, which has similar geography and demographics but varying regulations and laws. Bristol, VA imposes both sales and income taxes, while Bristol, TN has no state income tax but a higher sales tax rate. This distinction influences decisions for residents and businesses regarding location, investments, and financial planning. It is important to consider affiliation between the two cities when implementing any program.

Bristol suffered significant economic setbacks during the past ten years. The city had three profitable landfills, two of which are closed or in the process of being closed, and one that is no longer accepting waste due to legal or environmental reasons. Total remediation and closure efforts for two of these landfills are estimated to cost approximately $52 million, not including additional post-closure costs (Hearld Courier, 2024). Additionally, the city previously invested in a $50 million retail development project that has not developed fully enough to become profitable. Both financial setbacks left Bristol owing over $130 million in debt and cannot borrow any additional funds until 2042. (Herald Courier, 2024) Therefore, Bristol does not have adequate funds to simply purchase more recycling options for its citizens. Without immediate

intervention, Bristol will be unable to provide recycling options to their citizens and continue to fail in meeting a 25% recycling mandate.

Consequences

There are three critical consequences the lack of recycling creates: severe financial penalties, irreversible reliance on landfills, and negative environmental impacts. If Bristol does not meet the state's 25% recycling rate mandate, the city could face financial penalties of up to $250,000 annually. Bristol's existing $130 million debt burden severely constrains the city's financial capacity, and further penalties risk exacerbating its already precarious economic situation. In addition, a lack of recycling leads to increased waste being disposed of in landfills, as materials that could be repurposed are instead discarded as trash (Green City Times, n.d.). This is costly to Bristol as landfills operational costs are steadily increasing in Virginia, most recently by 11% in 2022. Landfills also have a finite capacity and as more was sent without recycling; they reach capacity much quicker, which could require Bristol to find a secondary landfill facility farther from the city. Finally, overflowing landfills, increased GHG emissions, depletion of natural resources, and air pollution negatively impact the environment. The constant production of new products from raw materials requires energy, much of which comes from fossil fuels. Recycling reduces the need for new materials, thus reducing energy consumption and GHG emissions (Green City Times, n.d.). These consequences demonstrate an urgent need for Bristol to develop a strategy to address this recycling issue.

Evidence Review

This evidence review will describe three different strategies aimed at increasing the recycling rate. The purpose of this review is to synthesize and categories the most effective recycling interventions aimed at increasing Bristol's recycling rate. It will draw insights from academic literature and cases studies concerning recycling practices, waste management strategies, and additional supportive research.

Strategy 1: Recycling Infrastructure

A foundational element of any successful waste management strategy is a well-designed recycling infrastructure. For Bristol, which currently lacks adequate recycling options, establishing this infrastructure is paramount to adequate achieving its recycling rate goals and avoiding financial penalties. A key decision in developing Bristol's recycling infrastructure is choosing between two system approaches: single-stream recycling and multiple-stream recycling. This section of the evidence review will explore key components, benefits, and drawbacks of both systems.

Single Stream vs Multiple Stream Systems

The key difference between single-stream and multi-stream recycling is whether residents are required to sort materials prior to collection. A single-stream recycling system collected household recyclables in a single commingled container and the mixed recyclables are then sorted at an MRF. A multiple-stream recycling system consists of residents separating recyclables into different categories and then transported to the MRF.

Single-stream recycling systems are likely to have higher recycling rates than multi-stream. Lakhan et al. (2015) examined the difference recycling performance between the two systems in Ontario, Canada. Using data from 223 provincial municipalities, the study showed that single-stream recycling programs recycle more material but face significantly higher material management costs. On average, single stream recycling increased municipal recycling rates by 4.11% but were 28.5% more expensive than multi-stream. The higher processing costs is likely due to the need for advanced sorting technology. However, it is important to recognize that Ontario, Canada is significantly different from Bristol, Virginia in population, size, economy, and governance which could limit the applicability of this study.

Multi-stream recycling systems tend to have slightly lower GHG emissions than single-stream recycling systems. Beradocco et al. (2022) conducted a study in an unnamed North American college city assessing the life cycle sustainability of these two systems. According to the study, a single-stream recycling system produced 10.56 kg CO_2/ton while multi-stream recycling systems produced 9.56 kg CO_2/ton. The increased energy consumption associated with the more complex sorting processes at MRFs is likely to contribute to the slightly higher emissions from single-stream recycling. However, recycling rate is the determining factor for both GHG emissions and cost.

Strategy 2: Reducing Landfill Waste

Reducing landfill waste will increase Bristol's recycling rate without implementing costly recycling programs. There are twelve materials that do not qualify for recycling in Virginia, including Styrofoam, batteries, and food waste (Central Virginia Waste Management Authority, n.d.). These materials are often disposed of in landfills rather than repurposed because they do not meet the criteria for recycling. By reducing and repurposing these materials, Bristol will not only decrease its total waste production but will also consequently increase its recycling rate without directly addressing the lack of recycling options available to citizens. Additionally, Bristol no longer has an operational landfill within the city and therefore must pay a neighboring landfall approximately $58 per ton of waste disposed of and the costs of transporting waste. Reducing the city's total waste production will also decrease its landfill costs.

Composting to Eliminate Food Waste

Each year, the United States produces 60 million tons of food waste, accounting for nearly 40% of the entire U.S. food supply (RTS, 2024). Virginia produced nearly 2.1 million tons of food waste, an 11.1% increase from 2016. An estimated 24% of municipal landfill input is food waste, indicating that residents are disposing of food waste in landfills rather than repurposing it (Peifer, 2024*).* An effective means to divert food waste from landfills is composting, which is the process of recycling organic materials into an amendment that can be used to enrich soil and plants (RTS, 2024).

There is well-established evidence that composting is an effective measure to minimize food waste in rural communities like Bristol (Buzby & Hyman, 2012). Niles (2020) collected data from the Vermonter poll, a statewide representative poll conducted annually, to determine the examining food waste management practices of Vermont residents. Over half of respondents were living in counties and classified as rural and reported being homeowners. In this study, 72% of residents reported managing food waste through backyard composting or feeding to livestock and 75% anticipated continuing this practice in the future. Rural households (13.7%) and homeowners (+14.1%) were more likely to compost backyards than urban households. Additionally, rural counties were less likely to support curbside collection programs for both composting and recycling (66.6% compared to 57,7%, $p < 0.046$). Overall, the study showed that residents living in rural regions like Vermont already have established composting practices. This evidence also suggests Bristol should focus on consumer education and backyard composting infrastructure to increase composting and recycling rates. Both Vermont and Bristol face similar challenges regarding waste management. These include insufficient road infrastructure and being considerably distant from urban areas where most recycling facilities are located (Niles, 2020). However, the considerable differences between the two regions need to be considered before generalizing this study. While Vermont has rural regions like Bristol, they have different incentive structures regarding recycling due to varying state legislation. They also have differing social demographics that may impact food waste management practices. It is important to consider these differences when determining whether composting is a viable alternative for Bristol.

Evidence suggests making composting more convenient for residents increases composting rates and reduces excess food waste. DiGiacomo et al. (2018) performed a randomized field experiment aimed at discovering whether convenience improves composting and recycling rates. The study lasted four months and the buildings participating in the study had no composting programs prior to the experiment. Researchers randomly assigned three buildings with similar characteristics to three different conditions: least convenient, more convenient, and most convenient. Convivence was defined as a function of distance with the shorter distance between the compost bin and the main garbage disposal area being more convenient. The building assigned the most convenient condition, which had compost bins placed on each floor, had composting rates increase by 70%, diverting 60 lbs. of compost from landfills per unit per year. Furthermore, when recycling stations were placed just meters away from suites, recycling increased by 147% and composting increased by 139%. This study suggests perceived convenience to be a large indicator of composting rates. It also suggests that it may be possible to boost both composting and recycling rates without changing the physical location of drop-off sites but rather changing the perception of how convenient the bins are to access (DiGiacomo et al., 2018). However, this study was performed in high-density residential buildings and 95% of participants were between the ages of 18 and 24, which is significantly different to the residential and age composition of Bristol. Therefore, due to these limitations, perceived convenience demonstrated in this study, may be difficult to achieve in Bristol.

Strategy 2: Citizen Participation and Support

Citizen Input and Involvement

Citizen participation and support is critical to the success of any recycling measure. Involving citizens in the design phase of recycling programs strongly correlated with increased participation, especially in voluntary programs. “Democratizing” the process created a sense of ownership, responsibility, and freedom among citizens. Communities that relied on citizen input found significantly higher participation rates. This effect increased voluntary programs than mandatory ones as they are more flexible in design and implementation. Other factors that influenced citizen participation and likelihood of citizen input included citizen opinion surveys, community meetings, and assistance from nonprofit organizations. A collaborative design process has proved to be an effective strategy for increasing citizen participation and supporting the costs for recycling programs.

Educational Nudges

Nudges can be an effective tool for marketing recycling to citizens. Nudges provide behavioral solutions to problems that have been assumed to originate from limitations in human decision-making (Loewenstein & Chater, 2017). A variety of nudges have proved effective in encouraging households to recycle by providing personalized information about their specific recycling behaviors. Milford et al. explored strategies to encourage household recycling and waste reduction through personalized information and social comparative feedback. The study designed a random experiment that assigned participants to one of three conditions: recycle group, quantity group, and control group. The recycling group received a letter describing their

recycling performance compared to the district average. The quantity group received a letter about their total waste compared to the average for households of similar size in their district, and the control group received nothing. The study lasted 20 months and participants' waste data was collected throughout. Researchers delivered two rounds of letters 9 months apart from one another where the second round contained updated information on changes in their recycling performance. The recycling group increased their recycling by 2 percentage points more than the control group. The quantity group showed a decrease in residual waste but an increase in paper waste, indicating a shift towards recycling rather than overall waste reduction. Most participants found the information in the letter useful and believed it influenced their recycling behavior.

Overall, evidence indicates that personalized information and social comparative feedback effectively increased recycling but had a limited impact on overall waste reduction. It may be effective for Bristol to share personalized information recycling to residents; however, the costs and time required to implement this program must be considered. It is also difficult to discern whether these nudges will be effective for Bristol given its differing geographical location and demographics.

Evidence Review Conclusion

This evidence review highlights three key strategies for increasing Bristol's recycling rate. A well-designed recycling infrastructure, particularly the choice between a single-stream and multiple-stream system, is essential to achieving higher recycling rate despite cost implications. Additionally, reducing food waste through composting can lower landfill contributions and improve the recycling rate. Finally, engaging citizens through participatory design and educational nudges fosters a motivated community which can also increase recycling efforts. While these strategies offer promising approaches, it is imperative for Bristol to consider local context and adapt these findings to align with the city's specific characteristics.

Policy Alternatives

To evaluate this issue, this report utilizes a tiered framework of alternatives. The framework consists of two distinct tiers of alternatives: infrastructure and supporting strategies. Figure 1 illustrates this two-tier system of alternatives. The first tier is the primary, first-order decision that must be made before anything else. It focuses on the type of recycling infrastructure implemented (single-stream recycling vs. multi-stream recycling) which is foundational to the alternative process. The second tier presents two supporting strategies (public education campaign vs. household composting) that are additional options that could aid Bristol in reaching their goal of a 25% recycling rate. These supporting strategies are independent of whether a single or multiple-stream recycling system is chosen. Each alternative carries its unique costs, implications for increasing the recycling rate, and impact on the community.

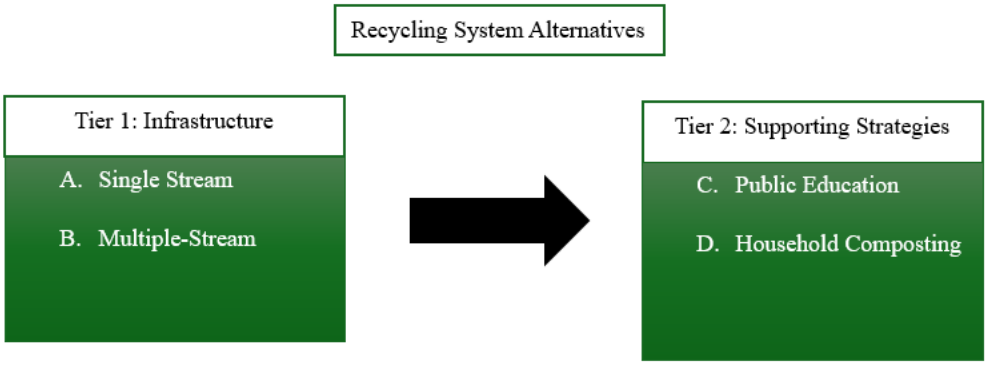

Figure 2. Tiered Framework of Recycling Alternatives for Bristol, VA

Tier 1: Infrastructure

The first tier of alternatives focuses on providing a recycling infrastructure for Bristol. This includes sorting, collection, and the disposal of recyclables. It is critical for the infrastructure to be established before moving forward with addressing any other relevant issues. There are two types of recycling infrastructure: single stream and multiple streams. Each method has distinct operational methodologies and implications for participation and efficiency. Figure 2 is from Wang (2006) and it illustrates the difference between the two systems.

A. Single-Stream Recycling System

Single stream recycling is a recycling system in which household recyclables are collected in a single contaminated collector (Lakhan, 2015) as shown in Figure 3. Households place all eligible recyclables in a designated bin provided by the municipality and drop off the materials at one of three drop off locations: Lee & Spencer Street, 1501 Euclid Avenue, and 2515 Valley Drive. These drop-off centers are accessible to all citizens and have already been implemented by the city's Solid Waste Department. Once delivered to a drop-off site, the recyclables will be delivered to the nearest material recyclable facility (MRF) which currently is the Tri-Country Recycling Inc. (33.1 mi from Bristol). The MRF is responsible for processing, sorting, and

addressing contamination recyclables. Single stream requires MRFs to implement increased mechanization to sort commingled material. Bristol will be responsible for the cost of sorting and necessary decontamination in addition to the baseline processing fee. The advantages of single stream recycling are the ability to process greater quantities of materials, minimize material management costs, and maximize recycling convenience and participation (Beradocco, 2022).

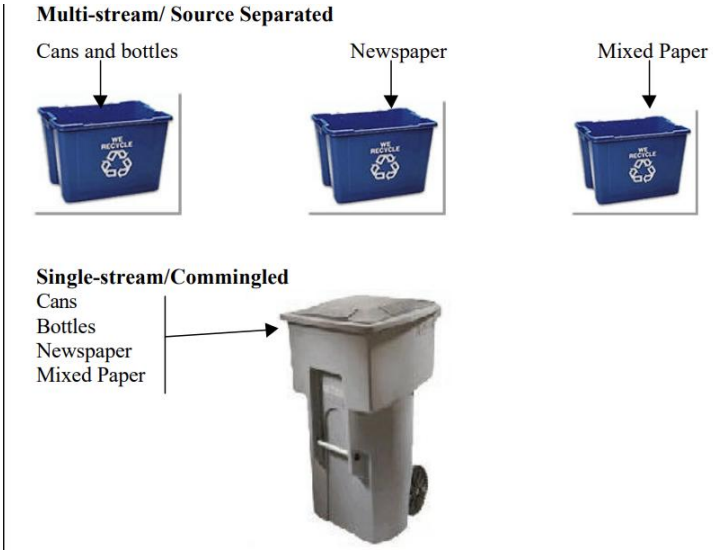

Figure 3. Single Stream versus Multiple Stream Recycling

B. Multiple-Stream Recycling System:

Multiple stream recycling operates in the same manner as single stream recycling but with one system requires greater effort from residents, sorting materials into designated bins for each material as shown in Figure 3. However, multiple stream recycling has the potential to significantly reduce contamination, leading to higher-quality recyclables and increased economic value. The number of streams in a recycling system depends on the number of materials residents must sort. General categories of materials include paper, plastic, glass etc. For each additional stream, Bristol is responsible for organizing drop-off centers accordingly and ensuring materials remain separated during transportation to the designated MRF. Once the recyclables are transported, the MRF is only responsible for processing the materials as they have been sorted prior and there is less contamination.

Tier 2: Supporting Strategies

The second tier of alternatives presents two supporting strategies that aim to increase the city's recycling rate with a more targeted approach. Both alternatives are suitable for single and multiple stream recycling systems and therefore are independent of the first tier.

C. Public Education Campaign

Citizen participation and support is critical to the success of any recycling measure. This alternative is aimed at increasing awareness, enhancing knowledge, and improving recycling participation. While the alternatives presented include basic information sharing to citizens, this alternative is a comprehensive municipal promotion and education program managed by the city government. It will not only inform citizens of how to utilize either single or multiple-stream recycling system but will also seek to motivate citizens to live a sustainable lifestyle. The target audience of this campaign is households and residents. This public education campaign is composed of three media: printed materials, community events, and social media campaigns. Printed materials will include brochures, flyers, and posters will be posted in high-traffic areas including the Bristol Public Library, City Hall, and community centers. It will also be important to engage with residents directly at popular community events such as the Bristol Rhythm & Roots Reunion festival, farmers markets, and sporting events. Finally, a social media campaign using platforms like Facebook, Instagram and Twitter will be used to share engaging content, infographic, and fellow resident's recycling stories. All education material and posts will outline recycling guidelines, educate citizens on what can be recycled, and the impact recycling will have on Bristol and the environment. The Bristol City Government will cover the costs of educational material.

D. Household Composting

Each year, the United States produces 60 million tons of food waste, accounting for nearly 40% of the entire U.S. food supply (RTS, 2024). Virginia produced nearly 2.1 million tons of food waste, an 11.1% increase from 2016. An estimated 24% of municipal landfill input is food waste, indicating that residents are disposing of food waste in landfills rather than repurposing it (Peifer, 2024*).* An effective means to divert food waste from landfills is composting, which is the process of recycling organic materials into an amendment that can be used to enrich soil and plants (RTS, 2024). This alternative is composed of a decentralized composting program on the household level. Rather than transporting food waste to an industrialized facility, decentralized composting is a community-based initiative that encourages residents to compost in their households. Bristol will provide each household with composting bins interested in participating in the program as well as provide information on composting techniques, maintenance, and benefits. Once they have composted, residents will have the choice to either use the byproduct of soil or sell it. Bristol will also set up composting sites at the three drop off centers listed in the previous alternatives for residents who are unable to compost at home. The byproduct from this communal will be shared amongst the Bristol community. The city will only be financially responsible for providing the composting bins and education materials.

Evaluation and Criteria

In comparing the different policy alternatives, I will evaluate based on the following criteria:

Estimated Effectiveness in Increasing Recycling Rate

Recycling rate estimates each alternative's projected improvement to Bristol's recycling rate. The recycling rate is calculated by dividing the total amount of waste recycled by the total amount of waste generated. The Virginia DEQ mandate is in terms of recycling rate. Therefore, it is important to assess each alternative's estimated recycling rate to determine whether the mandate can be met.

A score will be assigned along a simple *low, medium, or high* scale that estimates how well the alternative increases the total amount of recyclable materials, decreases the total waste generated by the city and increases the city's overall recycling rate. A *high* score will indicate that the alternative would exceed the 25% threshold. A *low* score will indicate that the alternative may increase the recycling rate, but the increase is either not clear or is likely below 10%. A *medium* score will meet somewhere in between with a clear explanation for where the recycling rates are and are not certain.

Evaluating the recycling rate is difficult. Accurate assessment of recycling rates is hampered by gaps in research and the wide variation in recycling rates across different locations and communities. The recycling rate is also difficult to calculate due to contamination which can significantly reduce the value and marketability of collected materials. Contamination of recyclable materials with non-recyclable items forces the entire batch to be landfilled, lowering the overall recycling rate.

Cost

Cost assesses the direct costs and indirect costs of the proposed alternative. Direct costs include the purchasing of necessary resources (bins, education materials etc.), transportation of recyclables, upkeeping and supporting drop off centers, and the additional salary for existing city employees to maintain the program. Indirect costs include the expenses associated with using landfills for waste disposal, administrative costs, and opportunity costs. Cost effectiveness will also assess the benefits for each alternative. Benefits include increased recycling revenue and reduced landfill disposal. Recycling revenue is generated from the sale of recyclable materials. Reduced landfill disposal is measured using tons of waste diverted from landfills.

Cost Effectiveness

Cost effectiveness is a ratio of the total cost estimate divided by the estimation of the total tonnage of recyclables for that alternative. The estimation for the total tonnage of recyclables was estimated based on the high, medium, and low score assigned.

The Tier 1 alternatives establish a recycling infrastructure and therefore hold the most responsibility for increasing the recycling rate. The Tier 2 alternatives are supporting strategies with the intention of improving the recycling rate by up to 10%. Cost effectiveness divides the

total cost by the estimated tonnage of recyclables using Bristol's most recent waste generation data for each alternative.

Environmental Stewardship

The Bristol City Government desires to improve the recycling rate to meet the state mandate while also upholding environmental stewardship, resiliency, and good global citizenship. Environmental stewardship criteria will assess whether an alternative is supportive of this goal. To further specify this criterion is qualitative and therefore will consider several supporting factors. These include GHG estimates measured in tons and the promotion of sustainable practices. GHG estimates will be acquired from relevant research. The promotion of sustainable practices will incorporate the uptake of sustainable practices other than recycling that have been such as the installation of renewable energy and participation in public transport or walking.

A score will be assigned along a simple *low, medium, or high* scale that estimates how well the alternative assesses environmental stewardship. A *high* score will indicate that the alternative would be implemented with very little GHG emissions and is very likely to promote other sustainable practices such as water conservation or energy efficiency. A *medium* score indicates that the alternative either can be implemented with very little GHG emissions or is very likely to promote other sustainable practices. A *low* score will indicate that the alternative will lead to a significant amount of GHG emissions and/or promote unsustainable recycling practices. Tier 1 alternatives produce more GHG emissions due to its extensive infrastructure. While Tier 2 alternatives are negligible compared to the emissions associated with tier one options, it is still important to consider their impact.

Political feasibility

Political feasibility assesses whether the alternative is likely to be supported by Bristol's city government and residents. It is a qualitative criterion and will be measured on a scale of high, medium, and low with high indicating a high likelihood of political feasibility. It includes the assessment of other factors including estimated time of implementation, the likelihood of citizen support, and the likelihood of city government support. It will also consider the complexity of each alternative as more complex programs are more difficult to garner support for in Bristol. To measure complexity, the number of departments and organizations required will be measured. This data will be acquired directly from the Bristol city government.

A score will be assigned along a simple *low, medium, or high* scale that estimates how well the alternative assesses political feasibility. A *high* score will indicate that the alternative would garner the support of both citizens and city government and be implemented within a reasonable timeline. A *medium* score indicates that the alternative either garners to the support of both citizens and city government or can be implemented within the timeframe. A *low* score indicates that Bristol is unable to implement within a reasonable timeframe and will not garner support from either citizens or city government.

Evaluation of Alternatives

Tier 1: Infrastructure

A. Single-Stream Recycling System

Estimated Effectiveness in Increasing Recycling Rate

If implemented fully, a single stream recycling system would significantly increase Bristol's recycling rate by placing the responsibility of sorting into the MRF rather than citizens. accepting a wide selection of acceptable materials. Accepting a wide range of materials and increasing container size would also increase the number of recyclable materials collected. Single-stream recycling increased per-resident recyclable collection by 77.5 pounds compared to multi-stream systems, particularly benefiting communities lacking existing recycling programs (Wang, 2006).

There are three relevant studies estimating the increase in recycling rates associated with single-stream recycling. First, a study conducted in Ontario, Canada estimated an average recycling rate of 14.8%. However, Ontario differs significantly from Bristol and has different characteristics including population size, regulation, and demographics (Lakhan, 2015). Second, a study conducted by the University of Miami estimated a 26.66% recycling rate for paper (Yasar, 2017). While this study had more similar demographics to Bristol, it focused only on paper which constitutes 26.5% of Bristol's total waste generation. The third study estimated a 65.5% average recycling rate for Fremont, Livermore, and San Leandro, California. However, like the Ontario study, there are key differences in population size, regulations, and demographics to Bristol, VA.

The average between these three studies estimates a **36%** increase in recycling rate and therefore receives a score of ***high***.

Cost

In 2015, the Waste Division of Ontario performed (WDO) a comprehensive cost analysis of both single and dual-stream recycling systems (Lantz, 2008). There are two primary costs associated with single-stream recycling: collection and processing. This study estimated the collection cost per ton to be $194.68 and the processing cost per son to be $136.82/ton (Lantz, 2008). Despite differences in age, income, and education levels between Ontario and Bristol, the Waste Diversion Ontario (WDO) data indicates that these demographic factors do not affect municipal recycling program costs. Overall, the total estimated cost of $298.87/ton.

There are several limitations to this study conducted by WDO. First, this study relied heavily on self-reported data from municipalities collected through the WDO data call. The researchers acknowledge the inherent limitations of self-reported data, including potential inaccuracies and inconsistencies but assume the reported data are representative of the actual costs of this option. Second, this study assumes that municipalities consistently implement a single-stream recycling program. Changes in program implementation, collection methods, or processing techniques within a municipality could alter the cost estimates. Finally, the study assumes stable market

prices for varied recycled materials throughout the analysis period as fluctuations in process could influence net costs.

In addition, recurring costs include labor, fuel, vehicle maintenance, insurance, and container procurement. The cost of labor per employee is estimated at $51,047/year using data from the Economic Research Institute (Erieri, n.d.). The average cost of diesel fuel in Virginia in 2024 is used as an estimate. The recycling trucks would travel approximately 20,500 miles per year and vehicle maintenance would cost approximately $22,500 per vehicle (AAA, n.d.). Insurance, estimated by the Leavitt group agency, would cost each vehicle between $9,000 and $12,000 per year (InsuranceHub, n.d.). Finally, container procurement would cost $37/household (Uline, n.d.).

To meet the state mandated recycling rate, Bristol needs to collect and process approximately 3,064 tons in recyclables. This estimate was acquired using the most recent data from the Viginia DEQ Locality Recycling Rate Report. Using this estimate, the total cost for this option is approximately to be **$915,800.**

Cost Effectiveness

The single-stream recycling system received a *high* score with an estimated recycling rate of 36% which is approximately 4,412 tons of recyclables per year. Dividing the total projected cost of $915,800 by 4,412 tons yields a cost effectiveness of **$208/ton.**

Environmental Stewardship

Single-stream recycling systems had slightly greater total GHG emissions than multi-stream recycling systems. Materials collected from a single-stream system require MRFs to sort, decontaminate, and sort which increases the facility's rate of emissions. However, single-stream systems collect all materials at one time compared to multi-stream systems. This decrease in collection leads to a decrease in GHG emissions from transportation. This reduction in transportation emissions is extremely relevant to Bristol, a rural community, where the nearest recycling facility is located a considerable distance from the city. For both systems, the waste composition significantly impacted on the projected GHG emissions. A higher proportion of valuable recyclables required less energy-intensive processes and decreased GHG emissions. Therefore, it is important for Bristol to implement strategies and encourage citizens to refrain from contaminating recyclables. While this alternative has decreased GHG emissions due to collection and increased diversion from landfills, the additional sorting and greater risk of contamination would lead to an increase in GHG emissions. Therefore, this alternative scored *medium*.

Political Feasibility

A single-stream recycling system would be politically feasible for Bristol to implement. Time of implementation is expected to be within a reasonable timeframe between 6 months to 1 year. There are also a greater number of MRF with capabilities for single-stream processing in the area surrounding Bristol. This also provides Bristol with the flexibility to transfer their recycling to another facility if prices are lower or it is a closer distance from the city. However, in the long term, this option may be limited due to the higher likelihood of contamination. Citizens are likely

to support this option as it does not require them to sort materials prior to depositing them. It is unknown whether the city government will support this alternative. While sorting responsibilities are placed on the nearest MRF, the risk of contamination levels significantly reducing the amount of quality recyclables may be too high. However, MRF processing technology is continuing to develop and continues to decrease the likelihood of contamination as well. This option received a ***medium*** score due to uncertainties regarding timeline feasibility, many potential MRFs, and the risk of contamination.

B. Multiple-Stream Recycling System

Multiple stream recycling operates in the same manner as single stream recycling but with one critical difference: households are expected to sort their recyclables prior to collection. This system requires greater effort from residents, sorting materials into designated bins for each material. However, multiple stream recycling has the potential to significantly reduce contamination, leading to higher-quality recyclables and increased economic value. The number of streams in a recycling system depends on the number of materials residents must sort. General categories of materials include paper, plastic, glass etc. For each additional stream, Bristol is responsible for organizing drop-off centers accordingly and ensuring materials remain separated during transportation to the designated MRF. Once the recyclables are transported, the MRF is only responsible for processing the materials as they have been sorted prior and there is less contamination.

Estimated Effectiveness in Increasing Recycling Rate

This option presents a lower risk of contamination, which enhances the quality and market value of the recycled materials. The yield rate for materials processed by this system 10% higher than single-single systems, providing Bristol with an opportunity to gain increased revenue (Lakhan, 2015). However, multiple-stream recycling systems are extremely dependent on whether citizens are willing to sort materials themselves. Due to households having to take additional time to source separate recyclables into their respective streams, this option would have reduced levels of household participation and overall lower recycling rate (Miranda, 2012). The success of this option relies heavily on the quality of sorting done by citizens. When individuals incorrectly separate recyclables from trash, it becomes a major source of contamination in the recycling stream, hindering improvements in recycling rates (Miranda, 2012). In addition, accepting a wide range of materials and increasing container size would also increase the number of recyclable materials collected (Lantz, 2008).

There are two studies estimating the effect dual-stream recycling system on a city's recycling rate. The first study examined the impact of switching from dual-stream to single-stream in Long Island, New York. This study estimated that a dual-stream system decreases the recycling rate by 10.3% (Tonjes, 2016). The second study estimated a 10.2% decrease when municipalities adopted a dual-stream system in Ontario, Canada (Lakhan, 2015). Using these two studies, the average recycling rate for multiple-stream recycling systems is approximately **10.25%** and therefore this option has a score of ***low***.

Cost

The same study used to estimate the collection and processing costs for single-stream recycling was used to estimate the costs of this option. The study assumes a dual-stream recycling system. The collection costs were estimated to be $200.66/ton, and the processing costs were estimated to be $91.99/ton. This option shares the same limitations as the previous one (Lantz, 2008).

The cost estimates for fuel, vehicle maintenance, labor, and insurance are the same as the single-stream recycling system. Container procurement is estimated to be $72 per household, one bin for each recycling stream (Lantz, 2008).

To meet the state mandated recycling rate, Bristol needs to collect and process approximately 3,064 tons of recyclables. This estimate was acquired using the most recent data from the Viginia DEQ Locality Recycling Rate Report. Using this estimate, the total cost for this option is approximately to be **$712,400.** This cost is considerably lower than single-stream recycling primarily due to the increased cost of sorting.

Cost Effectiveness

The single-stream recycling system received a *low* score with an estimated recycling rate of 10.25%, which is approximately 1,256 tons of recyclables per year. Dividing the total projected cost of $712,400 by 1,256 tons yields a cost effectiveness of **$567/ton.**

Environmental Stewardship

Multi-stream recycling systems, while requiring greater upfront in source separation, demonstrate a noteworthy level of environmental stewardship. This alternative had slightly lower GHG emissions compared to single-stream recycling systems (Beradocco, 2022). By minimizing contamination at the source, multi-stream systems often yield higher-quality recyclables, reducing processing energy and associated GHG emissions at the Materials Recovery Facility (MRF). For both systems, the waste composition significantly impacted on the projected GHG emissions. Therefore, it is important for Bristol to implement strategies and encourage citizens to refrain from contaminating recyclables (Fitzgerald, 2012). However, this option would also be likely to have increased collection rates to collect the various types of materials. This increased collection rates lead to greater transportation GHG emissions than single-stream systems. Considering its potential for reduced GHG emissions at the MRF and its promotion of source reduction through careful material separation, this option receives a ***high*** score of environmental stewardship.

Political Feasibility

It is uncertain whether citizens would support and participate in a multiple-stream recycling system. Citizens are required to sort materials before collection, which reduces convenience and may lead to lower recycling participation rates. The time required to build and implement the system is significant, and potential delays may be too lengthy for Bristol. The multi-stream system's requirement for separate collection streams introduces logistical complexities, increasing the potential for errors during implementation and potentially reducing overall efficiency. It is also uncertain whether the city government will support this option. Lower contamination rates will increase the quality of recyclables which can be sold at a higher price

and processed more efficiently. However, the Solid Waste Department will need to collect each stream of materials separately, requiring additional time and funds. It is unlikely whether the Solid Waste Department would be able to manage multiple streams of recycling due to budget and labor constraints. It is unlikely the option would be implemented within a reasonable timeline or garner enough support from both residents and city administration. Therefore, this option receives a score of ***low*** for political feasibility.

Tier 2: Supporting Strategies

C. Public Education Campaign

Estimated Effectiveness in Increasing Recycling Rate

If properly allocated, investments in recycling promotion and education would encourage behavioral changes which would improve the recycling rate by approximately **2%** and receive a score of ***low***. (Schultz, 1995). The goal of this option is to motivate citizens to adopt recycling as a regular habit through direct information sharing and targeted marketing strategies. A public education campaign would increase citizens' knowledge of recycling practices and its importance for Bristol. By informing the community about these benefits, a campaign would motivate individuals to recycle more. Additionally, emphasizing the urgency of the state's mandate can also encourage citizens to recycle more. A combination of social media campaigns and paper materials would be designated to reach different segments of the Bristol population effectively. According to the U.S. Census Bureau, Bristol exhibits some demographic homogeneity in terms of racial composition and socioeconomic status. These similarities allow for a targeted public education campaign, focusing on these largest subsets of the population which increases the likelihood of improving the recycling rate.

Cost

The cost for this alternative includes the following: printed materials, online resource page, educational workshops, and partnering with community leaders for events. Printed materials include brochures and flyers to distribute and post throughout Bristol. A template for printed brochures would cost between $20-$75 and printing a singular brochure would cost between $0.25 and $1.00. SpeedPro Commercial Graphics, located in Bristol TN, would create a template and produce the brochures. At least 7,327 brochures, one for each household, are required. Using an estimate of $0.625 per brochure, the printed materials will cost a total of $4,634.38. The city administration would manage the distribution of all printed and digital materials, utilizing town halls and community events. An online resource page would cost approximately $500. Educational workshops and partnerships with community leaders to organize events would cost approximately $4000 per year. To be effective, the public education program would need to be sustained for at least five years. It is also extremely likely that additional materials or events would need to be executed to adapt to the change in public need. Overall, the total cost for this option is approximately **$9,200/year.**

Cost Effectiveness

The public education campaign received a *low* score with an estimated effect recycling rate of 2% which equates to 245 tons of recyclables. Dividing the total projected cost of $9,129 by 245 tons yields a cost effectiveness of **$37/ton.**

Environmental Stewardship

This option employs practices that could hinder environmental sustainability. The production and distribution of brochures, flyers, and posters can contribute to emissions, especially if they are printed on non-recyclable paper or require significant transportation. Digital campaigns would have a smaller carbon footprint than physical materials. However, the use of both forms of media is necessary for a rural city like Bristol to target all target demographics. Printed materials are necessary for the portion of citizens who do not have internet access. While younger individuals may engage more with digital content, older residents or those not as familiar with technology may respond better to printed materials. Utilizing both formats allows for individuals to encounter the information through multiple channels, making them more likely to engage with the content and recycle more. Additionally, this option includes community events, workshops, and activities that involve transportation which could include emissions associated with travel and logistics. Therefore, this option receives a score of ***low*** for environmental stewardship.

Political Feasibility

This option is very feasible for the Bristol city government. The city already has the means to create physical and digital media content from previous projects. Therefore, it would take less than three months for the city to create and share the material with citizens. There are several central community locations and events that would reach a significant portion of citizens. However, the public education campaign must be well-targeted to motivate citizens to recycle. Bristol city council would also need to be well-informed about this issue to garner their support for the option as well. Therefore, this option receives a score of ***high*** for political feasibility.

D. Household Composting

Estimated Effectiveness in Increasing Recycling Rate

Composting is a common practice in rural communities such as Bristol. While food waste is not considered a recyclable material in Virginia, it comprises a significant portion of the city's total waste production which is used to calculate the recycling rate. This option focuses on organic materials, such as food scraps and yard waste, which typically make up a substantial portion of the waste stream. By composting these materials, Bristol would divert these materials from landfill, thereby increasing the city's overall recycling rate as well as reducing the tonnage of landfill waste.

Household composting also reduces the contamination of recyclables for both single and multiple-stream recycling systems. Contaminated recyclables are often disposed of in landfills, decreasing the recycling rate. When households participate in this composting option, they separate organic waste from recyclables. By keeping these materials separate, the amount of contamination that occurs in the recycling stream is significantly reduced. Overall, studies have

shown household composting would increase the household composting rate by approximately **10%** and therefore receive a score of ***high*** (Mengistu, 2018).

Cost

The total cost for this option includes the following: composting bins, labor, and preliminary education resources. The cost for composting bins is approximately $36/household. According to the U.S. Census Bureau conducted in 2023, Bristol has 7,327 households. Assuming approximately 20% of Bristol already compost, the total cost for composting bins is $52,700. According to a Chicago case study, it would take approximately 3-5 employees working approximately 5 hours per week to manage a composting drop-off center for Bristol. The average salary for a Solid Waste Department employee in Virginia is $21.40 per hour. Therefore, the total cost for labor is approximately $5,564. The cost of preliminary educational resources includes both printed materials and an online resource page. A template for printed brochures would cost between $20-$75 and printing a singular brochure would cost between $0.25 and $1.00. At least 7,327 brochures, one for each household, are required. Using an estimate of $0.625 per brochure, the printed materials will cost a total of $4,634.38. An online resource page would cost approximately $500. The total cost for educational resources is $547.50. Overall, the option will cost approximately **$63,000 per year.**

Cost Effectiveness

The household composting program received a *high* score with an estimated effect recycling rate of 10% which equates to 1,226 tons of recyclables. Dividing the total projected cost of $274,00 by 1,226 tons yields a cost effectiveness of **$52/ton.**

Environmental Stewardship

If implemented, this option would have a significant positive effect on the environment. Composting is a more sustainable alternative to landfilling and incineration for managing food waste. Both incineration and landfill disposal generate considerable methane and carbon dioxide emissions, both of which harm the environment. Diverting food waste from these disposal methods can significantly reduce GHG emissions. While composting could lead to GHG emissions from fossil fuel use in transportation, it is expected to be significantly less than the emissions saved from landfill diversion. In addition, Composting produces nutrient-rich soil that can be used for gardening, further promoting environmental sustainability. Composting offers significantly greater environmental stewardship than landfilling or incineration for food waste management, resulting in substantial GHG emission reductions and producing valuable soil; therefore, it receives a ***high*** score for environmental sustainability.

Political Feasibility

Rural residents and homeowners are more likely to compost (Niles, 2020). It is likely that a significant portion of Bristol residents have established composting practices or have been exposed to composting previously. Therefore, this option would be feasible for citizens to adopt with little concern. There is also very little additional burden on the Solid Waste Department. Once initial materials and instruction are provided, the Solid Waste Department could utilize the same collection and processing infrastructure put in place by either recycling stream. Like the

previous alternatives, it is uncertain whether the Bristol city council would support composting measures. While the existing composting practices and minimal Solid Waste Department burden suggest feasibility among Bristol residents, uncertainty regarding city council support results in a ***medium*** political feasibility score.

Outcomes Matrix

			Criteria				
			Recycling Rate	Cost	Cost Effectiveness	Political Feasibility	Environmental Stewardship
Alternatives	Tier 1	Single Stream	High	916000/year	$208/ton	Medium	Medium
		Multiple Stream	Low	712000/year	$567/ton	Low	High
	Tier 2	Public Education Campaign	Low	$9,129/year	$37/ton	High	Low
		Household Composting	High	$63,000/year	$52/ton	Medium	High

Figure 4. Outcomes Matrix

Figure 4 is the Outcomes Matrix, evaluating all alternatives using the five pieces of criterion. Green indicates a *high* score, yellow indicates a *medium* score, and red indicates a *low* score. Single-stream recycling boasts a high recycling rate but is expensive. Multiple-stream recycling has a low recycling rate but is less costly and environmentally superior. The primary difference between single-stream and multi-stream recycling systems lies in their participation rates, which are affected by the added sorting requirements of the multi-stream approach. Public education campaigns are cost-effective but yield low environmental benefits. Household composting, while expensive, achieves high recycling rates and strong environmental stewardship with medium political feasibility. Single-stream and composting are recommended due to their high recycling rates and strong environmental performance, despite the higher costs, as they offer the best balance of effectiveness and sustainability, although political considerations may necessitate further evaluation.

Recommendations

Tier 1: Single-Stream Recycling System

Bristol should implement a single-stream recycling system as their primary infrastructure with collection managed by the Solid Waste Department and processing outsourced to the nearest MRF facility.

It is critical for Bristol to develop a plan to improve the recycling rate. Currently, the city is running out of time and currently has no infrastructure in place to address this issue. Single-stream recycling simplifies sorting, encouraging greater participation from residents. Although more expensive than multi-stream recycling, this system's potential for significantly increasing the recycling rate aligns with Bristol's primary objective. A single-stream system is also mor politically feasible for the city. By consolidating recycling to a single stream, the Solid Waste Department's collection process is dramatically simplified which increases the likelihood of this program's success. This streamlined approach simplifies the sorting process, minimizing confusion, and encourages broader community engagement. Ultimately, the substantial increase in recycling materials outweighs the increased operational costs. For Bristol VA, a single-stream recycling system presents a compelling salutation to improve recycling rates.

Tier 2: Household Composting Program

To support the single-stream recycling system, Bristol should also implement a composting program, providing citizens with the necessary resources to compost their food waste and offering a drop-off composting site.

A household composting program offers Bristol, VA, a practical and effective approach to improving the city's recycling rate. By diverting organic waste from landfills, this option directly reduces landfill burden, improves the recycling rate, and lowers disposal costs. Furthermore, composting creates nutrient-rich compost which supports sustainable agricultural practices within the community. While there are significant initial costs to implement this program, there are very little recurring costs, making it more economically feasible for Bristol in the long term. However, there is a slight tradeoff between environmental stewardship and political feasibility. This program's success depends on the support of citizens. Concerns about odor, pests, or inconvenience might lead to resistance, impacting citizens and city officials' support of the program. Additionally, it is more difficult for the city to ensure residents are following composting guidelines without resorting to overly strict enforcement measures. These tradeoffs must be considered during this program's implementation. By providing the necessary educational material, Bristol would empower residents to actively participate in the city's efforts to increase recycling. The resulting benefits, coupled with potential cost savings, make household composting a worthwhile investment for Bristol's future.

Implementation

To ensure successful implementation, Bristol must overcome two issues: finding a suitable MRF and financing both programs without contributing to the city's current debt. Selecting an acceptable MRF facility is critical to the success of this recommendation. Bristol's current debt of $130 million makes it difficult to finance both recommended programs. Both the single-stream recycling system and household composting program represent a long-term investment in the city's recycling infrastructure. Therefore, a robust and transparent financial plan is critical to secure funding. The discussion of stakeholders and the next steps will address both implementation issues.

Stakeholders

There are five main stakeholders: residents, city council and administration, Solid Waste Department, the selected MRF, and grant providers. Each of these stakeholders has a role vital to the success of the project. Residents will be mandated to participate in the single-stream recycling and household composting program.

Residents will need to understand and follow the guidelines of both programs to ensure materials are being sorted, collected, and processed efficiently. Public education campaigns tailored to each program, emphasizing the convenience of both, will be vital to encouraging participation.

The Bristol city council and administration will provide overall policy direction, approve financial planning, and secure necessary funding through budget allocation, grant applications, and potential user fees or taxes. They will also be responsible for communicating the plan to the public and addressing any concerns or questions from residents.

The role of the Solid Waste Department will be to manage daily operations of both programs. This includes the logistics of collection for the single-stream recycling (route planning, truck maintenance, personnel management), establishing and maintaining drop-off locations, and overseeing the household composting program (distribution of bins and educational materials). Each stakeholder's active involvement is critical to the program's success.

The selected MRF will process all the collected recyclables. Their capacity, efficiency, and proximity to Bristol are key factors in determining the financial viability and environmental impact of the single-stream system. The city council and administration will negotiate contracts to ensure the MRF meets quality and efficiency standards.

Finally, securing funding for both recommended programs is crucial, given Bristol's current financial constraints. The city will need to research and apply for relevant grants from organizations such as the Environmental Protection Agency (EPA). Although Bristol qualifies for some of these grants, there is uncertainty about the availability of EPA funding in the future. The city may also need to explore other funding avenues such as private sector partnerships or bonds. The successful acquisition of funding is essential for the plan's implementation.

Next Steps

Figure 5 illustrates the five stages of implementation: Public outreach and the implementation of the household composting program, MRF selection and financing, recycling logistics, a pilot program, and final implementation.

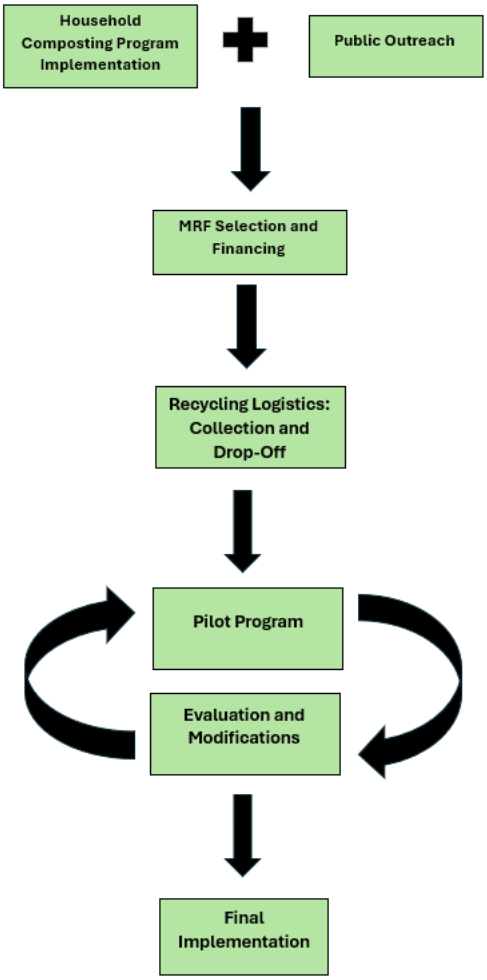

Figure 5. Implementation Flow Diagram

Household composting can be implemented immediately without an initial testing phase as it is lower in cost and only requires extensive oversight in the initial phases. In addition, it is important to conduct public outreach prior to implementation to increase resident participation and diffuse potential opposition. This outreach will involve sending public surveys to all residents, with questions designed to gather information about their current recycling practices and their preferences for future recycling programs. The survey will be managed by the Bristol government The following implementation phases will be focused on the single-stream recycling system.

Bristol should research and select a suitable MRF. The MRF's proximity to Bristol, capacity, and processing capabilities will directly impact on the cost-effectiveness and efficiency of the single stream recycling system. A poorly chosen MRF could lead to increased contamination, higher processing costs, and ultimately, lower recycling rates. Specifically, the MRF needs to be equipped to handle the increased volume and diverse types of materials expected from a single-stream system. The MRF's location should minimize transportation costs and environmental impacts. With an average gasoline price of $3 per gallon, the optimal location for the MRF is within a 30-mile radius of Bristol to minimize transportation costs. It is recommended to conduct site visits and additional reviews to ensure the chosen MRF is properly equipped and strategically located to support Bristol's recycling rate objective. Tri-Cities Waste Management is the closest MRF facility that meets these requirements. It is located approximately 15 miles from Blountville, TN and is equipped to process all materials collected from a single-stream system. The route between Tri-Cities Waste Management and Bristol is shown in Figure 6.

Figure 6. Route Between Tri Cities Paper and Bristol

While researching and selecting an MRF, Bristol should simultaneously be looking to secure funding for both the single-stream recycling and household composting programs, which is crucial for Bristol, despite its existing $130 million debt. The financial plan required will include the cost breakdown listed previously in the evaluation of each alternative. It will also identify potential external revenue streams such as grants and projected cost savings from reduced landfill usage. Bristol is eligible for the Environmental Protection Agency's (EPA) Solid Waste Infrastructure for Recycling Grants for Communities, a promising funding opportunity. Once grant research has been exhausted, Bristol should look towards allocating a portion of the city's existing budget for the Solid Waste Department to finance both programs. The city may also explore the possibility of creating a dedicated fund for these initiatives through user fees or a small tax increase, clearing communicating the environmental and economic benefits to residents.

Once MRF selection and financing has been completed, Bristol's next step is to design collection and drop-off routes. Waste and recycling collection need to be separate due to contamination risk, differing routes, and public health concerns. There are three components necessary to design the most efficient routes: residential mapping, waste distribution, and the evaluation of the current waste collection infrastructure. Using residential mapping, Bristol needs to identify residential areas and incorporate information about population density, road networks, and traffic patterns. Collection routes will be optimized using Bristol's Solid Waste Department data on waste volume and type generated in each area. The final component of route design evaluates the city's current waste collection infrastructure, including the number of existing collection and drop-off points, capacity of garbage trucks, and the availability of drop-off locations. Combining all three components should yield a preliminary route design that will need to be updated as the programs evolve.

The final step of single-stream implementation is the pilot program which should be conducted in a limited area of Bristol before city-wide implementation. This allows for a smaller-scale test to identify and resolve potential issues without affecting the entire city's waste management system. The general principle for pilot programs is to include 10-20% of the target population as it is likely representative of the entire population and manageable in terms of resources, logistics, and time. Using the average of this principle, Bristol should involve approximately 15% of the total population of Bristol (North Dakota State University, n.d.). This ensures that the pilot includes a representative sample of Bristol's population without depleting Bristol's resources.

Throughout the pilot program, data must be collected on key measurements including recycling rate, route collection efficiency, and MRF performance. This testing phase should also gather feedback from all stakeholders using surveys, focus groups, and open forums. Based on the collected data and feedback received, necessary adjustments should be made which may include modifications to collection routes or changes in public education materials. Once data analysis is complete and necessary adjustments have been made, the single stream recycling system can be adopted city-wide. Monitoring and evaluation should continue after city-wide implementation to adjust as needed. Figure 5 illustrates the stages of implementation.

Conclusion

Bristol must develop a plan to meet the state's 25% recycling mandate to avoid disastrous financial penalties and improve the quality of life of its citizens. Implementing a single-stream recycling system enhanced by a household composting program should create the necessary foundation and support to meet this goal. The convenience and efficiency of the single-stream recycling system should increase citizen participation and thus improve the recycling rate by approximately 35%. Similarly, the household composting program encourages residents to sustainably repurpose their food waste, increasing the recycling rate by approximately 10%. Utilizing both programs simultaneously should yield a 46% recycling rate which exceeds the 25% state mandate. While exceeding the mandate may have higher costs, it leads to long-term savings by reducing landfill usage and associated costs. Additionally, the increased recycling rates generate additional revenue and ensures Bristol consistently meets the mandate each year. To implement the recommended recycling programs, Bristol must select a suitable MRF and secure funding despite the city's current debt. The city should research and apply for relevant grants, design efficient collection routes, and conduct a pilot program to test the single-stream recycling system before city-wide adoption. The household composting can be implemented as soon as possible. Continuous monitoring and adjustments should endure both programs' success. The implementation of a single-stream recycling system and household composting program will not only help Bristol meet the city's state mandate but also foster environmental stewardship, community engagement, and long-term economic benefits for the city and its residents.

Bibliography

Lakhan, C. (2015). *A comparison of single and multi-stream recycling systems in Ontario, Canada. Resources*, *4*(2), 384–397. https://doi.org/10.3390/resources4020384

Wang, J. (2006). *All in one: Do single-stream curbside recycling programs increase recycling rates?* (Master's thesis, University of California, Berkeley).

Tonjes, J. (2018). *Conversion from dual stream to single stream recycling results in nuanced effects on revenues and waste stream amounts and composition.* Department of Technology and Society, Stony Brook University. https://www.sciencedirect.com/science/article/abs/pii/S0921344918302714

Peifer, K. (2024, January 4). *Virginia's food waste, charted*. Axios. https://www.axios.com/local/richmond/2024/01/04/virginias-food-waste-charted "Majority of rural residents compost food waste: policy and waste management implications for rural regions."

RTS. (2024). *Food waste in America: Statistics & facts*. RTS. https://www.rts.com/resources/guides/food-waste-america/

Buzby, J. C., & Hyman, J. (2012). Total and per capita value of food loss in the United States. *Food Policy, 37*(5), 561-570. https://doi.org/10.1016/j.foodpol.2012.06.002

Niles, M. T. (2020). Majority of rural residents compost food waste: Policy and waste management implications for rural regions. *Frontiers in Sustainable Food Systems, 3*, 123. https://doi.org/10.3389/fsufs.2019.00123

DiGiacomo, A., Wu, D. W.-L., Lenkic, P., Fraser, B., Zhao, J., & Kingstone, A. (2018). Convenience improves composting and recycling rates in high-density residential buildings. *Journal of Environmental Planning and Management, 61*(2), 309-331. https://doi.org/10.1080/09640568.2017.1305332 "Theory of Planned Behavior" (https://www.sciencedirect.com/topics/medicine-and-dentistry/theory-of-planned-behavior#:~:text=The%20Theory%20of%20Planned%20Behavior%20assumes%20that%20individuals%20have%20deliberate,difficulty%20to%20perform%20the%20behavior).

Berardocco, C., Delawter, H., Putzu, T., Wolfe, L. C., & Zhang, H. (2022). Life cycle sustainability assessment of single stream and multi-stream waste recycling systems. *Sustainability*, *14*(24), 16747. https://doi.org/10.3390/su142416747

Lantz, D. (2008). *Single stream versus two stream recycling: an examination of costs and recovery rates of current programs in Ontario, Canada.* WIT Transactions on Ecology and the Environment, Vol 109. https://books.google.com/books?hl=en&lr=&id=LAnQCwAAQBAJ&oi=fnd&pg=PA415&dq=multiple+stream+recycling&ots=_a_1eRx6d3&sig=uY9NqQG0tka56jxEZUcne1uhJo8#v=onepage&q&f=false

Fitzgerald G., Krones J., Themelis N. Greenhouse gas impact of dual stream and single stream collection and separation of recyclables. Vol. 69. Resources, Conservation and Recycling. https://www.sciencedirect.com/science/article/abs/pii/S0921344912001449?via%3Dihub

Mihai, F. C., & Ingrao, C. (2018). Assessment of biowaste losses through unsound waste management practices in rural areas and the role of home composting. *Journal of Cleaner Production*, *172*, 1631–1638. https://doi.org/10.1016/j.jclepro.2016.10.163

Jakus, P. M., Tiller, K. H., & Park, W. M. (1997). Explaining Rural Household Participation in Recycling. *Journal of Agricultural and Applied Economics*, *29*(1), 141–148. doi:10.1017/S1074070800007628

Lakhan, C., (2014). Exploring the relationship between municipal promotion and education investments and recycling rate performance in Ontario, Canada. *Resources, Conservation, and Recycling*, Vol. 92(222-229). https://www.sciencedirect.com/science/article/abs/pii/S0921344914001499

Thomas, C. (2001). Public understanding and its effect on recycling performance in Hampshire and Milton Keynes. Recycling, Conservation, and Recycling. Vol.32(259-274). https://www.sciencedirect.com/science/article/abs/pii/S0921344901000659

https://www.sciencedirect.com/science/article/abs/pii/S0921344912001449

Erieri. (n.d.). *Garbage truck driver salaries in Virginia*. Erieri. https://www.erieri.com/salary/job/garbage-truck-driver/united-states/virginia

AAA. (n.d.). *Virginia gas prices*. AAA Gas Prices. https://gasprices.aaa.com/?state=VA

Uline. (n.d.). *Rubbermaid recycling tote bin, 18-gallon, blue*. Uline. https://www.uline.com/Product/Detail/H-2836BLU/Recycling-Containers/Rubbermaid-Recycling-Tote-Bin-18-Gallon-Blue?pricode=WA9364

InsuranceHub. (n.d.). *What does semi-truck insurance cost?* InsuranceHub. https://insurancehub.com/what-does-semi-truck-insurance-cost/

Mengistu, T., Gebrekidan, H., Kibret, K. *et al.* Comparative effectiveness of different composting methods on the stabilization, maturation and sanitization of municipal organic solid wastes and dried faecal sludge mixtures. *Environ Syst Res* **6**, 5 (2018). https://doi.org/10.1186/s40068-017-0079-4

Aboelmaged, M. (2021). E-waste recycling behaviour: An integration of recycling habits into the theory of planned behaviour. *Journal of Cleaner Production*, 278, 124182. https://doi.org/10.1016/j.jclepro.2020.124182

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179-211. https://doi.org/10.1016/0749-5978(91)90020-T[1].

Buzby, J. C., & Hyman, J. (2012). Total and per capita value of food loss in the United States. *Food Policy, 37*(5), 561-570. https://doi.org/10.1016/j.foodpol.2012.06.002

Central Virginia Waste Management Authority. (n.d.). *What to recycle*. Central Virginia Waste Management Authority. https://cvwma.com/programs/residential-recycling/what-to-recycle/

City of Bristol, Virginia. (n.d.). *Public Works*. City of Bristol, Virginia. Retrieved September 17, 2024, from https://www.bristolva.org/164/Public-Works

City of Bristol, Virginia. (n.d.). *Recycling*. City of Bristol, Virginia. Retrieved September 17, 2024, from https://www.bristolva.org/440/Recycling

DiGiacomo, A., Wu, D. W.-L., Lenkic, P., Fraser, B., Zhao, J., & Kingstone, A. (2018). Convenience improves composting and recycling rates in high-density residential buildings. *Journal of Environmental Planning and Management, 61*(2), 309-331. https://doi.org/10.1080/09640568.2017.1305332 "Theory of Planned Behavior" (https://www.sciencedirect.com/topics/medicine-and-dentistry/theory-of-planned-behavior#:~:text=The%20Theory%20of%20Planned%20Behavior%20assumes%20that%20individuals%20have%20deliberate,difficulty%20to%20perform%20the%20behavior).

Hagman, W., Andersson, D., Västfjäll, D., & Tinghög, G. (2015). Improving acceptability of nudges: Learning from attitude towards opt-in and opt-out policies. *Journal of Economic Psychology, 42*, 290-299. https://doi.org/10.1016/j.joep.2014.06.008

Herald Courier. (n.d.). *Southwest Virginia economy resilient in face of population declines*. Herald Courier. Retrieved September 17, 2024, from https://heraldcourier.com/news/local/business/southwest-virginia-economy-resilient-in-face-of-population-declines/article_17924502-3fbb-11ef-b220-6f0a9292f831.html

Hotta, Y., Visvanathan, C., & Kojima, M. (2016). Recycling rate and target setting: Challenges for standardized measurement. *Journal of Material Cycles and Waste Management, 18*(1), 14-21. https://doi.org/10.1007/s10163-015-0361-3

Kang, H.-Y., & Schoenung, J. M. (2005). Electronic waste recycling: A review of U.S. infrastructure and technology options. *Resources, Conservation and Recycling, 45*(4), 368-400. https://doi.org/10.1016/j.resconrec.2005.06.001

Katz, C. (2019, March 7). Piling up: How China's ban on importing waste has stalled global recycling. Yale Environment 360. Retrieved December 5, 2024, from https://e360.yale.edu/features/piling-up-how-chinas-ban-on-importing-waste-has-stalled-global-recycling

Lahmeyer, J. (n.d.). *Johnson City-Kingsport-Bristol (Combined Statistical Area)*. City Population. Retrieved September 17, 2024, from https://www.citypopulation.de/en/usa/combmetro/304__johnson_city_kingsport_/

League of Women Voters of South Hampton Roads. (n.d.). *Local recycling study*. League of Women Voters of South Hampton Roads. https://my.lwv.org/virginia/south-hampton-roads/local-recycling-study#:~:text=Those%20who%20opt%20in%20would,City%20and%20delivered%20to%20SPSA

Loewenstein, G., & Chater, N. (2017). Putting nudges in perspective. *Behavioural Public Policy, 1*(1), 26-53. https://doi.org/10.1017/bpp.2016.7[1].

Milford, A. B., Øvrum, A., & Helgesen, H. (2015). Nudges to increase recycling and reduce waste. *NILF Discussion Paper, 2015-01*. Norwegian Agricultural Economics Research Institute. https://core.ac.uk/download/pdf/285987303.pdf[1].

Niles, M. T. (2020). Majority of rural residents compost food waste: Policy and waste management implications for rural regions. *Frontiers in Sustainable Food Systems, 3*, 123. https://doi.org/10.3389/fsufs.2019.00123

Nordfalk, F., & Høyer, K. (2017). The rise and fall of an opt-out system. *Scandinavian Journal of Public Health, 48*(4), 400-404. https://doi.org/10.1177/1403494817745189

O'Connell-Domenech, A. (2023, June 23). *Americans are throwing out half their household recyclables. Here's why*. The Hill. https://thehill.com/changing-america/sustainability/climate-change/4062424-americans-are-throwing-out-half-their-household-recyclables-heres-why/

Oregon State University. (n.d.). Recycling processes. Oregon State University. Retrieved December 5, 2024, from https://fa.oregonstate.edu/sites/fa.oregonstate.edu/files/recycling/resources/MR_Class/chapter_4_recycling_processes.pdf

Patel, P. (2024, July 28). *Electronic waste is a gold mine waiting to be tapped*. Chemical & Engineering News. https://doi.org/10.1021/cen-102-23-0001

Peifer, K. (2024, January 4). *Virginia's food waste, charted*. Axios. https://www.axios.com/local/richmond/2024/01/04/virginias-food-waste-charted "Majority of rural residents compost food waste: policy and waste management implications for rural regions."

RTS. (2024). *Food waste in America: Statistics & facts*. RTS. https://www.rts.com/resources/guides/food-waste-america/

RubyHome. (n.d.). Recycling statistics and facts. RubyHome. Retrieved December 5, 2024, from https://www.rubyhome.com/blog/recycling-stats/

School. Retrieved September 25, 2024, from https://news.climate.columbia.edu/2020/03/13/fix-recycling-america/

U.S. Census Bureau. (n.d.). QuickFacts: Bristol city, Virginia. U.S. Department of Commerce. Retrieved December 5, 2024, from https://www.census.gov/quickfacts/fact/table/bristolcityvirginia/BZA110222

U.S. Department of Agriculture. (n.d.). *Composting*. U.S. Department of Agriculture. https://www.usda.gov/peoples-garden/food-access-foodwaste/composting#:~:text=Composting%20is%20the%20process%20of,to%20enrich%20soil%20and%20plants

U.S. Environmental Protection Agency. (2020, November 17). *National recycling goal: Recycling rate measurement*. U.S. Environmental Protection Agency. https://www.epa.gov/circulareconomy/national-recycling-goal-recycling-rate-measurement "Recycling rate and target and setting: challenges for standardized measurement."

U.S. Environmental Protection Agency. (2024). Regulation and policy. In *EPA.gov*. Retrieved September 25, 2024, from https://www.epa.gov/plastics/regulation-and-policy

U.S. Environmental Protection Agency. (2024, February 22). U.S. national recycling goal. U.S. Environmental Protection Agency. Retrieved December 5, 2024, from https://www.epa.gov/circulareconomy/us-national-recycling-goal

U.S. Environmental Protection Agency. (n.d.). U.S. recycling system. U.S. Environmental Protection Agency. Retrieved December 5, 2024, from https://www.epa.gov/circulareconomy/us-recycling-system

U.S. Environmental Protection Agency. (n.d.). *Recycling basics and benefits*. U.S. Environmental Protection Agency. Retrieved September 17, 2024, from https://www.epa.gov/recycle/recycling-basics-and-benefits

University at Buffalo. (2022, March 29). *UB researchers develop new method to recycle rare earth elements*. University at Buffalo. Retrieved September 17, 2024, from https://www.buffalo.edu/news/releases/2022/03/029.html

Virginia Administrative Code. (n.d.). *Solid waste management regulations*. Virginia Law. Retrieved September 17, 2024, from https://law.lis.virginia.gov/admincode/title9/agency20/chapter130/

Virginia Department of Environmental Quality. (2019). *Report on the impact of recycling requirements*. Retrieved from https://rga.lis.virginia.gov/Published/2019/SD7/PDF

Virginia Department of Environmental Quality. (n.d.). *Local, state, and regional solid waste planning*. Virginia Department of Environmental Quality. Retrieved September 17, 2024, from https://www.deq.virginia.gov/our-programs/land-waste/solid-hazardous-waste/solid-waste/local-state-and-regional-solid-waste-planning

Wahab, S. N., & Lim, F. Y. J. (2022). China's National Sword Policy Reaction To Southeast Asia's Waste Trade And The Transition To A Circular Economy. Journal of Technology and Operations Management, 17(1), 1–10. https://doi.org/10.32890/jtom2022.17.1.1

Green City Times. (n.d.). Circular economy. Green City Times. Retrieved March 31, 2025, from https://www.greencitytimes.com/circular-economy/#:~:text=GHG%20emissions%20resulting%20from%20excessive%20burning%20of,less%20production%20and%20less%20harmful%20emissions%20overall.

North Dakota State University. (n.d.). Voluntary recycling in Quito: Factors associated with participation in a pilot programme. NDSU Institutional Repository. Retrieved March 31, 2025, from https://library.ndsu.edu/ir/items/ea83bc6a-c7fc-403b-b40c-a8b0a27b89b6