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Conducting a Greenhouse Gas Lifecycle Anlaysis of Waste-to-Energy Incineration versus Recycling in Auburn, Maine

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Completed in partnership with the Auburn Recycling Committee

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EXECUTIVE SUMMARY

Recycling programs are under stress worldwide, as low commodity prices and environmental initiatives in China increase costs for municipalities. These challenges are being felt acutely in Auburn Maine, a small city which has long struggled with recycling; its recycling rate is currently less than one-fifth of the 40% statewide recycling rate. To address the twin challenges of increasing costs and a low recycling rate, the Auburn City Council created a recycling committee, which was tasked with evaluating recycling options for the city. Part of this evaluation involves a greenhouse gas lifecycle analysis of waste-to-energy incineration versus recycling of the city's waste. We were tasked with conducting this analysis and helping the city develop a balanced waste management strategy which considers both economic and environmental impacts under several waste management scenarios.

Using costs and greenhouse gas emissions as key metrics of comparison, our analysis developed four waste management scenarios, each of which assumes that different amounts of waste will be sent to waste-to-energy incineration, recycling, and composting, costs different amounts of money, and results in different levels of greenhouse gas emissions. Auburn's current waste management strategy costs about $1.1 million and results in 9000 tons CO2e emissions per year. Expanding recycling would cost an additional $75,000, reduce emissions by more than 75%, and increase Auburn's recycling rate from 8% to an estimated 30%. Expanding recycling and adding a composting program would cost an additional $225,000 over current costs but could result in net-negative emissions. Replacing the city's recycling program with a composting program would cost about $50,000 less than the current strategy and result in an approximately 10% reduction in emissions. Eliminating recycling would cost Auburn about $150,000 less than the current strategy but increase emissions by about 20% to 10,500 tons CO2e per year.

Based on our analyses, we recommend that Auburn continues and expands its recycling program through a new contract with EcoMaine, considers implementing a composting program with a local company such as We Compost It!, and implements an educational program to expand local knowledge of waste management best practices.

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1: INTRODUCTION

Plastic is the instantly recognizable symbol of our single-use, consumer-driven society. More than 8.3 billion tons of plastic has been produced since the 1960s (Kosior et al. 2019), including more than 300 million tons in 2016 alone (Milios et al. 2018). Global plastic production is expected to double by 2035 and quadruple by 2050 (Milios et al. 2018). The U.S. is the world's largest producer and consumer of plastic, responsible for 20% of worldwide waste generation despite having less than 5% of the world's population (Garcia & Robertson 2017). The U.S. nationwide recycling rate for plastic is 8.8% (Garcia & Robertson 2017). More than 90% of plastics, valued at more than $8.3 billion annually, are thus landfilled and subsequently lost to the economy after one short, initial use (Kosior et al. 2019; Garcia & Robertson 2017). Low recycling rates also mean that over 90% of plastics are created from virgin feedstock, further increasing natural resource usage (Kosior et al. 2019). Indeed, 6% of global oil production is used for plastics creation and recycling all plastic worldwide would save 3.5 billion barrels of oil, worth $176 billion, per year (Garcia & Robertson 2017). And though plastic is often considered to be the poster child for single use waste, other forms of waste like paper and metal use similar amounts of resources for a similarly short single use. There are often substantial barriers to recycling all recyclable materials: lack of demand and a fragmented market for recycled materials, contamination, fragmented plastic waste creation and collection, a lack of incentives to maximize the recyclability and reusability of products and packaging, and a lack of incentives for participation in recycling programs (Milios et al. 2018).

Despite these barriers, recycling programs in many parts of the U.S. have successfully reduced waste going to landfills or incinerators, provided environmental benefits, and saved communities money (National Waste and Recycling Association 2019). When well-implemented, recycling can compete with other waste management strategies like landfilling or incineration on issues of cost and can also dramatically reduce greenhouse gas emissions and virgin material usage (Chester et al. 2007; Iriarte et al. 2008; Gradus et al. 2017). In recent years, the costs of recycling have gone up, however, as the market for many recyclable materials has collapsed. Increasing contamination standards, which often necessitate dedicated collection for recyclables, plus separation, sorting, and recycling, have had an outsized impact on increasing costs (Gradus et al. 2017). As the costs of recycling have increased, the environmental benefits have decreased: separated collection, processing, and recycling of recyclable waste can now cost over $200 per ton, an expense that has been shown to take money from other municipal environmental initiatives like walking and biking paths, public transportation, and school energy efficiency upgrades (Gradus et al. 2017).

Policy changes in China are primarily responsible for the collapse of the global recycling market. Until 2016, China processed more than half of the world's recyclables, but recent environmental initiatives have blocked the importation of foreign waste (National Waste and Recycling Association 2019). In 2013, the "Green Fence" policy cracked down on the illegal importation of low-grade foreign waste and raised contamination standards; next in 2017, the "National Sword" program introduced an array of environmental policies, including strict air quality regulations and even stricter contamination standards for foreign waste; then, in 2018, China banned the importation of 24 post-consumer waste materials, including all plastics (National Waste and Recycling Association 2019; CalRecycle 2020). These policies have collectively led to the collapse of global prices for recyclables. Between 2016 and 2018, the price of recycled cardboard fell from $105 to $70 per ton, and the price of plastics fell from $32 to $4.70 per ton (National Waste and Recycling Association 2019). And though shipments of recyclables to countries like Vietnam and Indonesia have increased since China's policies went into effect, the ability of these countries to process vast amounts of waste is far lower. At the same time, many Asian countries like India and Thailand are following China's lead and implementing similarly strict contamination standards (CalRecycle 2020).

Maine is one of six states with a statewide recycling rate over 40%, and in many Maine communities with strong recycling and composting programs, less than one-third of all household waste is sent to landfills or incinerators (Washuk 2019). But with the exception of Livermore, recycling rates in Auburn's Androscoggin County are among the lowest in the state– less than 8% in Auburn, Lewiston, and the surrounding towns (Washuk 2019). Meanwhile, the per-ton rate paid by Auburn to recycle is one of the highest in the state. Auburn currently pays $54 per ton to collect trash and $53 per ton to incinerate its trash, but $158 per ton to collect recyclables and $117 per ton to process recyclables (personal communication, Ralph Harder, 2/12/2020), far more than similarly-situated Maine towns like Farmington, South Portland, and Biddeford, which all pay less than half as much as Auburn (personal communication, Annie Sedoric and Erin Bucki, 4/13/20).

Though Auburn's total waste production has been stable over the past two decades, costs have been rising over the past few years (personal communication, Ralph Harder, 2/12/2020; Rice 2019). In 2019, the Auburn City Council considered suspending the city's recycling program outright but created a recycling committee to study the issue instead (Rice 2019). The committee's charge is to "...identify the key impacts of the current recycling program, compare the current model with different models Auburn could adopt," identify the costs associated with the current recycling program, compare that program to things that other municipalities have done to adapt to the changing market, and "...create a public education and awareness campaign for the recommended changes" (City of Auburn Recycling Committee n.d.).

Fundamentally, the question the recycling committee needs to address is this: What should a fiscally conservative, but forward-looking community do to maximize environmental benefits and minimize costs? (personal communication, Ralph Harder 2/12/2020). Thus, perhaps the most pressing issue to address is whether Auburn can spend its current recycling budget better. In other words, are there contracts which can be renegotiated or contractors which can be switched to increase Auburn's recycling rate without spending additional money? An unpopular pay-per-bag proposal in 2014 could have boosted recycling participation but caused an uproar. Less controversial options could involve using a different recycling contractor, such as EcoMaine, or implementing a composting program.

Creating a greenhouse gas lifecycle is one way to broadly understand the economic and environmental costs associated with various waste management choices. Conducting a full product lifecycle encompasses raw material acquisition, manufacturing, product use or consumption, and final disposal via landfill, incineration, or recycling (Franklin Associates 2011). Each step requires energy inputs and generates waste outputs, and thus contributes to the overall greenhouse gas emissions associated with a product's lifecycle. For the purposes of this analysis, the post-consumer portion of the lifecycle–namely, the waste disposal options available to Auburn and the associated environmental and economic costs–is the primary concern.

Our project has the following aim, objectives, and deliverables:

***Aim*:** This study aims to compare the costs and greenhouse gas emissions associated with recycling, incinerating, and composting household waste, and help Auburn develop a balanced waste management strategy which considers both economic and environmental impacts under different scenarios.

Objective 1: Understand local and global waste management dynamics and the relative merits of recycling, incinerating, and composting various forms of household waste (e.g., plastic, organic waste, paper, metal, glass, etc.).

Objective 2: Create scenarios which weigh the environmental and economic impacts of recycling, incinerating, and/or composting different materials to inform Auburn policymakers on the costs and benefits.

Deliverable 1: A written report describing the results of a comparative life cycle assessment of recycling and local waste-to-energy trash incineration in Auburn, with transparent acknowledgment of all data used and assumptions made throughout.

Deliverable 2: A presentation to the Auburn City Council developed in partnership with the Auburn Recycling Committee, which describes the results of our analyses and makes waste management policy recommendations.

This report proceeds as follows: The next section elaborates briefly on the waste management options available to Auburn. The third section lays out our methodological approach. The fourth section presents and discusses our results. And the final section makes policy recommendations based on our research.

2: AUBURN'S WASTE MANAGEMENT OPTIONS

Before continuing, it is important to elaborate briefly on the waste management options available to the City of Auburn. Maine Waste-to-Energy (MWE), an Auburn-based waste incinerator, is currently the destination for about 90% of Auburn's municipal waste (personal communication, Ralph Harder, 2/12/2020). Owned by 12 member communities in the lower Androscoggin River Valley, MWE incinerates 72,000 tons of waste per year and generates 3.6 megawatts of electricity, enough to power about 2500 homes (Maine Waste-to-Energy n.d.; personal communication, Ralph Harder, 2/12/2020). Maine Waste-to-Energy member towns currently produce more waste than the facility can process: 13% of total, non-recyclable waste produced in the 12 towns is currently diverted to the Lewiston Landfill (personal communication, Ralph Harder 2/12/2020). Whereas MWE charges $53 per ton for waste (including ash landfilling costs), the Lewiston Landfill charges $78 per ton, increasing the waste management costs for the member communities (personal communication, Ralph Harder, 2/12/2020). Thus, diverting some waste from MWE, perhaps via increased recycling or the introduction of municipal composting, could save Auburn some or all of the additional expenses associated with landfilling MWE's surplus waste (personal communication, Ralph Harder, 2/12/2020).

The incinerator at MWE burns 90% of the waste it receives by volume, with the remaining 10% transported as ash to the Lewiston Landfill (Maine Waste-to-Energy n.d.). All metals are also sorted out of the ash and recycled (Maine Waste-to-Energy n.d.). Dioxins and furans are mostly removed using a lime and water mix, mercury is mostly removed using carbon injection, and particulates are captured in fabric filters and sent to the Lewiston Landfill (Maine Waste-to-Energy n.d.).

Maine Waste-to-Energy is not the only waste management facility available to Auburn, nor is it the only facility it currently uses. Casella Waste Systems in Lewiston is currently the destination for the 8% of Auburn's waste stream which is recycled (Casella n.d.; personal communication, Ralph Harder, 2/12/2020). Casella is a zero-sort recycling facility, and also currently has the recycling collection contract for Auburn (Casella n.d.; personal communication, Ralph Harder, 2/12/2020).

There are also at least two waste management facilities which Auburn does not currently use. We Compost It! is an Auburn-based composting company which has implemented curbside composting in municipalities like Portland, Brunswick, and Kennebunk (We Compost It! n.d.). Should Auburn decide to implement composting, We Compost It! would likely be the contractor used. Finally, EcoMaine, which recycles nearly 50% of the waste it processes, composts nearly 20%, and incinerates about 30%, is another waste management facility which Auburn has the option to use as a contractor and has reportedly considered using in the past (EcoMaine n.d.; personal communication, Ralph Harder, 2/12/2020).

3: METHODOLOGICAL APPROACH

3.1: CONTEXTUALIZATION

To gain a better understanding of the topic, we compiled research on the waste management options available to Auburn: waste-to-energy, composting and recycling. The information we gathered was used to inform our determination of each option's economic and environmental advantages in a broad context and help us understand the issue of waste management more fully. The data collection phase included gathering information from both local and national sources. The data we collected from general sources allowed us to better understand things like the energy potential of different materials, the ability of different materials to be recycled, composted, or incinerated, the emissions associated with each type of waste processing option, and the economic considerations associated with each waste management option. The Auburn specific data included information on Auburn's waste collection and recycling programs, as well as specific waste processing destinations like Casella, Maine Waste-to-Energy, and EcoMaine. After compiling both general information about waste management options and local knowledge about Auburn, we scaled our general findings to Auburn. This included steps like accounting for the distance to waste processing facilities, differences in waste management budgets, and what is politically feasible based on our conversations with local partners.

3.2: OUTREACH

Incorporating local knowledge was integral to our analyses. Based on our research of local waste management options, we called or spoke in person with the following people and organizations with knowledge about issues of waste management and asked the following questions: Members of the Auburn Recycling Committee, and representatives of Maine Waste-to-Energy, Casella Waste Systems, EcoMaine, and We Compost It! (see Appendix A for a list of the questions we asked; some questions were answered via website research).

3.3: Developing Scenarios

After collecting both the local and global data, we developed a series of waste management scenarios designed to provide the Auburn Recycling Committee and City Council with a suite of easily comparable waste management options. Each scenario quantifies the economic and environmental implications of using various waste management strategies for various forms of waste. Following the creation of scenarios, we evaluated these waste management options based on several criteria in order to develop recommendations. We weighed these options via three key considerations:

1. The key consideration was *cost*, namely the amount of money each scenario would cost the city of Auburn to implement.
2. *Environmental impact* was the second key criterion. We define this as the total amount of greenhouse gases, in CO2 equivalents, that will be emitted by processing Auburn's waste under each scenario.
3. Finally, we considered what is *most politically feasible* and *practical*, based on economic, environmental, and local factors.

3.4: Sharing Results

We created a presentation oriented around comparing the waste management scenarios we developed and analyzed. We introduced and explained the relative merits of the various scenarios based on cost, expense, and plausibility, then offered recommendations based on our research. This report summarizes these same findings.

4: RESULTS AND DISCUSSION

4.1: ANALYSIS OF COMMON WASTE CATEGORIES AND MANAGEMENT STRATEGIES

4.1.1: Paper

Paper is one of the most commonly recycled materials in both households and businesses. The United Kingdom, for example, has managed to achieve a 72% recycling rate for paper via public education (Arjowiggins N.d.). This rate is extremely high and has had substantial environmental benefits; recycling 17 tons of paper instead of sending it to the landfill can prevent close to 5 tons CO2e from being released into the atmosphere (Arjowiggins N.d.). As evident from the success of the U.K. in recycling paper products, there are clear environmental advantages to recycling paper. The U.S. has not followed the lead of the U.K., however. This may be a result of the low market value for paper as a recycled material and a lack of incentives for manufacturers to use recycled materials (Arjowiggins N.d.). Particularly over the past few years, the market for recycled paper has decreased to the point where there is virtually no place to sell recycled paper without taking a loss, as the price for recycled paper has fallen from $100 per ton in 2017 to about $10 per ton in 2019 (Resource Recycling). The collapse of this market paired with papermaking efficiency improvements resulting in a more than 15% reduction in papermaking emissions has resulted in paper recycling not being a priority in the U.S. (Two Sides Na 2018). As a result of low recycling rates, paper has increasingly ended up in landfills and incineration plants. As a result of this trend, the EPA conducted a study to determine the greenhouse gas emissions released when paper is incinerated and landfilled. They found that the emissions from recycling mixed paper are -3.53 tons CO2e per ton of waste, the emissions from incineration are -0.51 tons CO2e per ton of waste, and the emissions of sending paper to a landfill are about 0.13

tons CO_2e per ton of waste (EPA 2016). As a result, it is clearly more environmentally beneficial for paper products to be recycled rather than incinerated or sent to a landfill. These environmental considerations must be weighed alongside the economic considerations of municipalities as they consider where to send their paper products.

4.1.2: Plastic

Plastics are the largest and most complex form of household waste. Though there are hundreds of varieties of plastic, most are categorized into plastic numbers 1-7 (Franklin Associates 2011). While there remains modest demand for plastic numbers 1 (PETE) and 2 (HDPE) in the global recycling market (EPA 2018), plastics 3-5 (PVC, LDPE, and PP) can only be recycled in advanced facilities and are typically landfilled or incinerated after collection (Franklin Associates 2011). Even for plastics 1 and 2, however, prices have become volatile in the past few years; supply now often outstrips demand, and the landfilling and warehousing of surplus or unsellable recyclables is increasing (EPA 2018). The collapse of the market for recycled plastic is largely due to increasing cleanliness standards and improved environmental regulations in China, which has purchased most U.S. recyclables since the 1990s–in 2019, U.S. plastic waste exports to China fell 35% (EPA 2018). Still, recycling remains by far the most environmentally responsible post-consumer disposal option: Only about one-tenth of the approximately 1.5-2 tons of CO_2e associated with virgin plastics manufacturing are released during plastics recycling. In other words, creating new plastics from recycled plastics results in a 90% reduction in greenhouse gas emissions, versus virgin plastic manufacturing (Franklin Associates 2011). Meanwhile, there are between 1.25 and 3.01 tons of CO_2e associated with plastics incineration (depending on the type of plastic), and 0.04 tons of CO_2e associated with landfilling plastic (Franklin Associates 2011).

4.1.3: Metal

The market for recycled metal is the only recycling market which has not collapsed over the past few years (EPA 2018). Indeed, recycled metal is worth about $2000/ton, making it by far the most valuable form of recyclable waste, with prices expected to rise further over the next few years (EPA 2018; Popular Mechanics 2018). The market for recycled metal is so strong because creating metal products from virgin materials is so expensive and energy-intensive: Producing one ton of aluminum, for example, releases 10 tons CO2e, more than four times as many greenhouse gas emissions as any other form of waste (Popular Mechanics 2018). Meanwhile, only 0.4 tons CO2e are associated with recycling metal and manufacturing new products. Additionally, unlike some plastics, metal does not need to be downcycled, and can easily be re-manufactured into the same products indefinitely (Popular Mechanics 2018). Thus, recycling is by far the best waste management solution for metal. It cannot be incinerated (any metal which enters an incinerator is recovered at the end of the process and recycled) (Maine Waste to Energy n.d.) and releases no emissions in landfills (Popular Mechanics 2018), but the environmental impacts of not recycling are enormous. Many metal containers are covered by Maine's "Bottle Bill;" with a redemption rate of 86%, most metal cans (and plastic bottles) are recycled on a separate, non-municipal waste track (Bottle Bill Resource Guide n.d.).

4.1.4: Glass

Most recycled glass has some value. The price of the glass varies greatly depending on its purity rating, however. Any purity under 80% has no real market and will have to be sent to the landfill, however 95% purity glass can be sold for up to $10 per ton and anything above 95% purity can be sold for between $70 and $100 per ton; Colored and sorted glass cullet can also be sold for between $60 and $80 per ton (Recycling Product News 2017). The market for recycled glass is projected to continue to grow in the years ahead. Curbside pick-up and deposit programs are the two main routes through which glass is recycled (Global Market Insights 2019). The emissions released from recycling glass are -0.28 tons CO2e per ton. Incinerating glass results in 0.03 tons CO2e per ton and landfilling results in 0.02 tons CO2e per ton (EPA 2016).

4.1.5: Organic Waste

There are a variety of different waste management strategies for organic waste, including composing, incineration and landfilling. According to a study done by the University of Georgia, the average cost per ton for organic waste to be composted in the U.S. is $72, which represents an average per-ton savings of $61 compared to the U.S. average for incineration and landfilling (University of Georgia 2017). Although these prices are dependent on local factors, having a general understanding of the price comparison between landfilling and composting organic matter is beneficial. We Compost It! is an Auburn-based composting contractor which would be an option should Auburn pursue a composting program. We Compost It! offers a curbside pick-up program in Brunswick, Portland and Kennebunk for compostable materials, namely food scraps, coffee grounds and filters, meats and bones, eggs and seafood shells, paper plates, napkins and dairy products (We Compost It n.d.). The environmental impact of different management strategies for organic waste is -0.16 tons CO2e per ton for both composting and incineration, and 1.0 tons CO2e per ton for landfilling (EPA 2016). This suggests that organic waste could be sent to a waste-to-energy or composting facility with similar environmental implications.

4.2: The Economic and Environmental Costs of Various Waste Management Strategies

4.2.1: Cost of the strategies

Waste management costs vary across the five waste destinations analyzed. The cost per ton to compost organic matter with We Compost It! is the cheapest followed by incineration by Maine Waste to Energy, recycling with EcoMaine, landfilling and finally recycling with Casella (Figure 1). When considering the economics of recycling, the market for the repurposed materials is also a key aspect of the process. An economic advantage of recycling is that certain materials can be repurposed and sold at a higher value than it costs to recycle the materials. Certain materials,

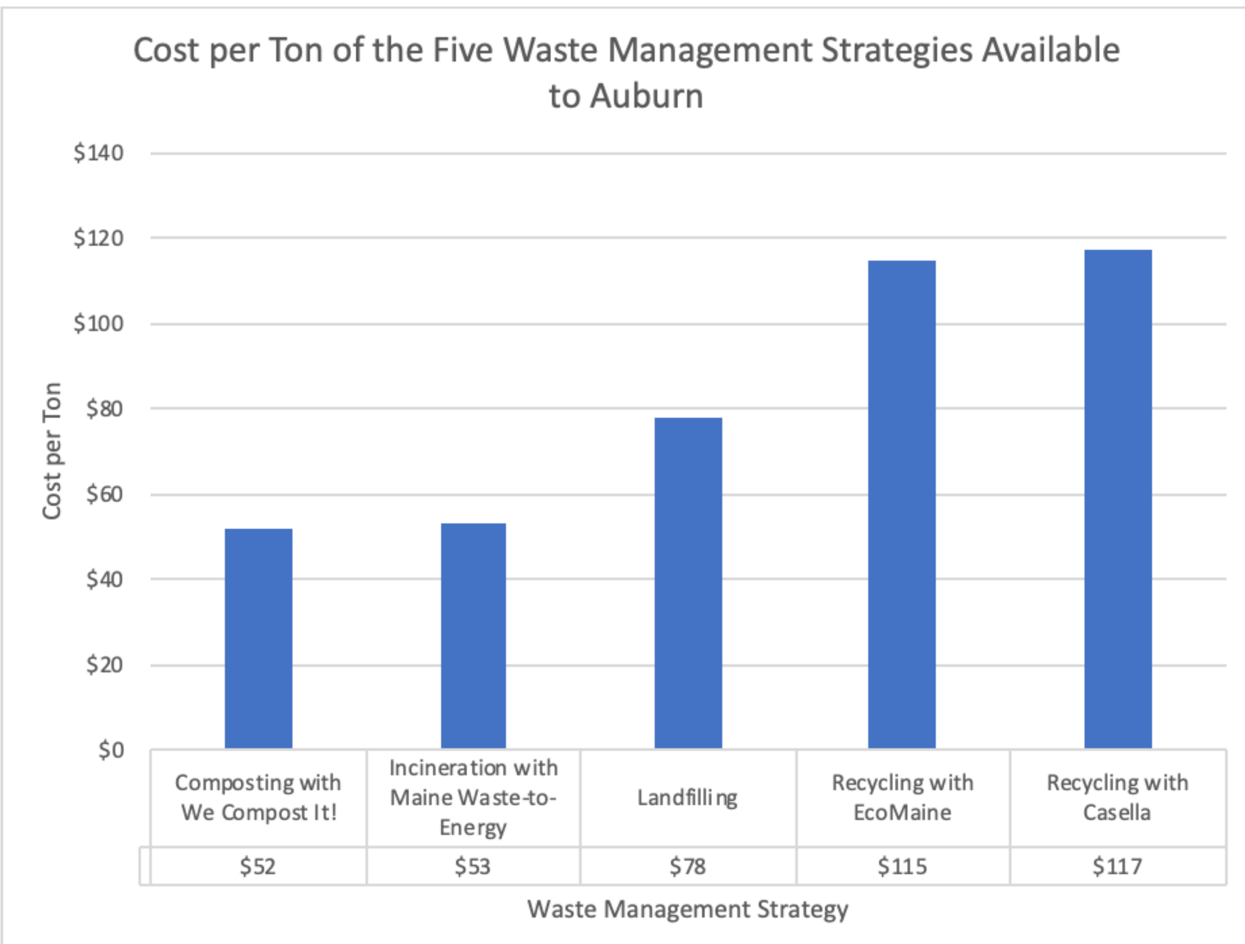

Figure 1: Cost per ton for the five main waste management strategies available to Auburn.

such as metal, have a much higher value when they are recycled. Although there are markets for many recycled materials, the market for metals and plastic #1 and plastic #2 are the largest. For these materials there are profits to be made by selling the materials once they have been recycled (Figure 2).

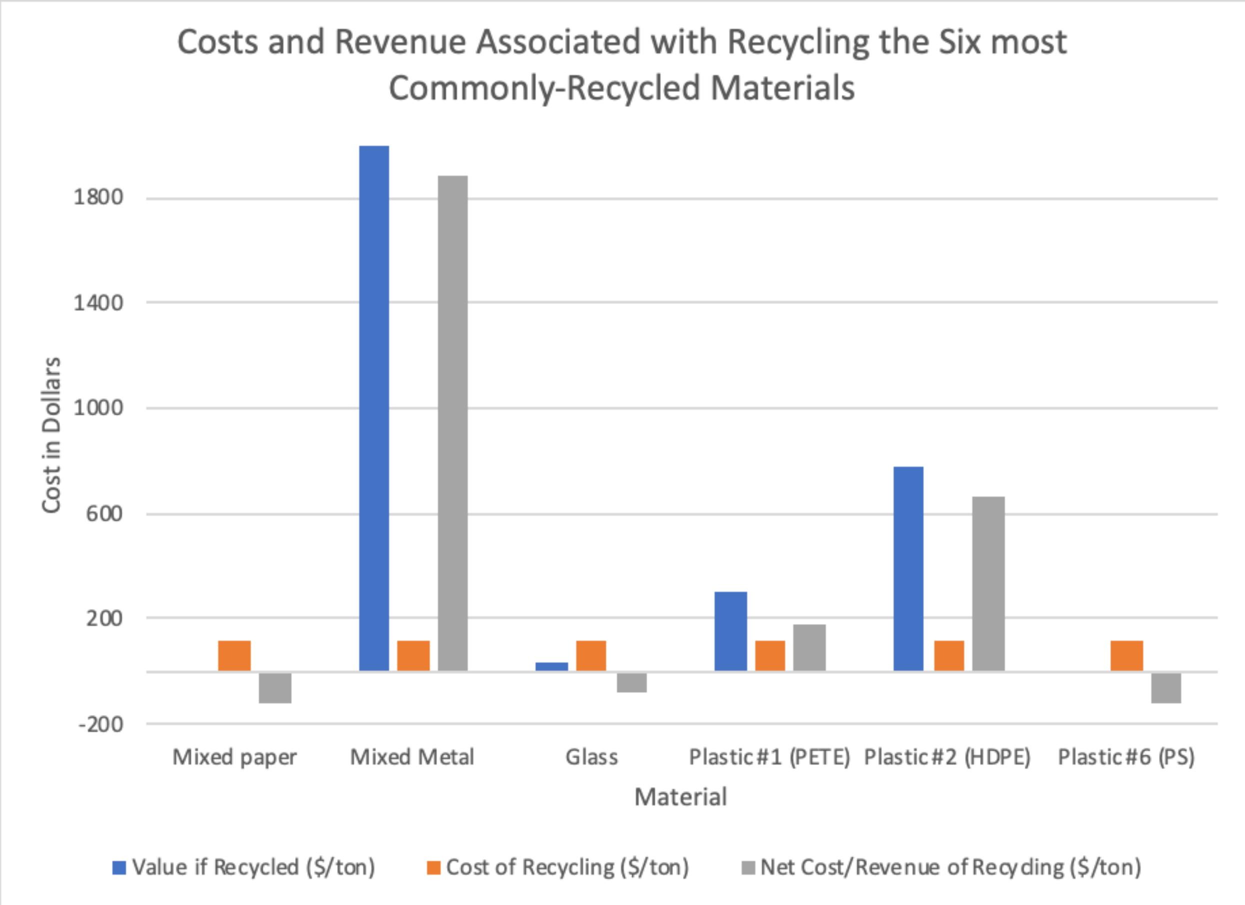

Figure 2: Costs and revenue associated with recycling the six most commonly recycled materials (mixed paper, mixed metal, glass, and plastics 1, 2, and 6).

4.2.2: Greenhouse Gas Emissions Associated with the Strategies

Waste management emissions vary by material. When considering where it is most environmentally efficient to send waste, it is best to understand the greenhouse gas emissions from each material at each end location. Each material has at most three possible end locations. Using data from a 2016 EPA study, each of the materials was ranked to determine the most and least environmentally efficient strategies. Using the emissions values for each strategy, it is clear that recycling is the most efficient strategy for each of the materials that are recyclable, while composting and waste to energy are most efficient for organic waste. Landfilling is the least environmentally efficient option for each of the materials except for plastic and glass, which both are least efficiently disposed of when they are sent to a waste to energy plant (Table 1). The emissions from recycling each of these materials does not fully encompass the greenhouse gas emissions saved from this process because when these materials are recycled, the emissions associated with producing products from virgin materials are avoided. The production of metal is highly energy intensive and recycling it can significantly reduce emissions. Plastics 1, 2, and 6 also each require high levels of emissions to create and as a result the recycling of those materials can save large amounts of emissions (Figure 3). When considering the emissions avoided by recycling rather than creating new materials, it is clear that recycling is the most environmentally efficient waste management strategy for all forms of recyclable waste.

	Composting	**Recycling**	**WTE**	**Landfilling**
Paper	-	-3.53	-0.51	0.13
Plastic	-	-1.02	1.23	0.2
Metal	-	-4.34	-	0.02
Organic Waste	-0.16	-	-0.16	0.2
Glass	-	-0.28	0.03	0.02

Table 1: Emissions (in tons CO2e per ton of waste) associated with the four main waste management strategies. Options symbolized in green indicate the strategy which results in the fewest emissions, and options in red symbolize the strategy with the highest emissions.

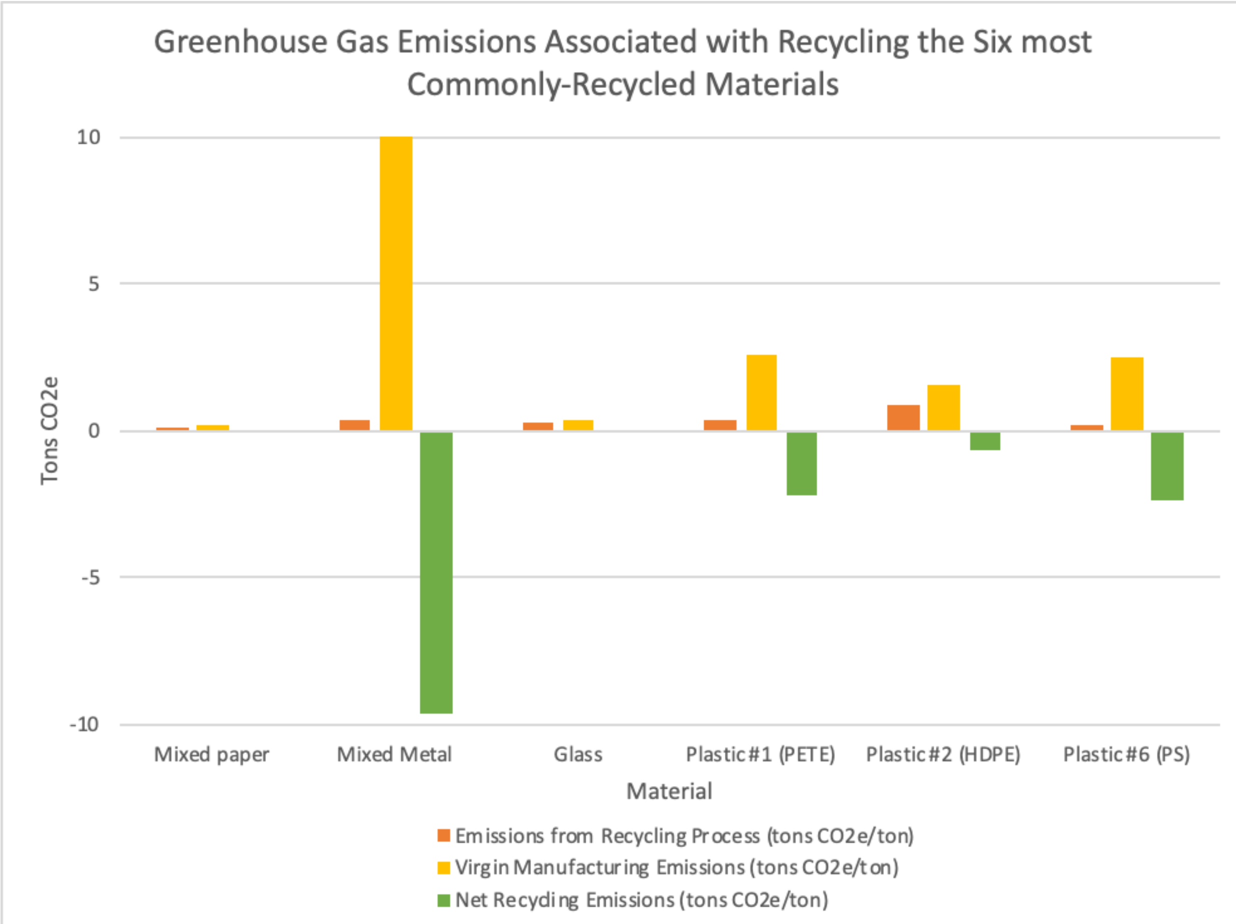

Figure 3: Greenhouse gas emissions associated with recycling the six most commonly recycled materials (mixed paper, mixed metal, glass, and plastics 1, 2, and 6).

4.2.3: Emissions Associated with Waste-to-Energy

Considering that over 90% of Auburn's waste is currently sent to Maine Waste-to-Energy, a brief exploration of the merits and concerns associated with this form of waste management is needed. These types of advanced facilities are increasingly popular worldwide, both as a solution to declining landfill capacity, and as a source of electricity (Chen 2018). The electricity produced by these facilities is not without greenhouse gas emissions, however; generating one kilowatt hour of electricity via waste incineration releases as much as 2.5 times as many greenhouse gas emissions as generating that electricity from coal (Energy Justice Network n.d.). Indeed, incinerating one ton of mixed plastics uses 78.2 kilowatt hours of electricity, and produces 2.27 tons of CO_2, 0.12 kg of CO, 0.48 kg of NO_2, 0.21 kg of particulates, 28.86 grams of SO_2, 4.2 grams of VOCs, and 27 kg of solid waste residue (Chen et al. 2019). The process also generates 1214 kilowatt hours of electricity, for a net production of 1135.8 kilowatt hours (Chen et al. 2019). Plastics are the most polluting form of household waste typically incinerated, and rubber is the most polluting form of industrial waste (Chen 2018).

A major concern with waste-to-energy is the fact that some states and countries, including Maine, consider incineration to be a "renewable" source of electricity. Thus, this technology takes funding from and competes with other, less polluting renewable electricity sources instead of fossil fuel electricity sources. By subtracting the methane avoided from landfills, the emissions from recycling facilities, the emissions from offsetting fossil fuels, and the emissions from transportation, some calculations consider incineration to be a net-zero source of electricity (Chen et al. 2019; Energy Justice Network n.d.). This calculation is misleading. All waste disposal options, and sources of electricity have associated emissions but, in places like Maine where more than three-quarters of the electricity mix is renewable (Figure 4), waste-to-energy is the most polluting source of electricity in the state (Figure 5). Though the net-emissions from incineration are often lower than landfilling (Chen et al. 2019) and waste-to-energy is often the best waste management option available to municipalities, it is important to acknowledge the concerns and shortcomings associated with waste-to-energy and recognize that this ostensibly "renewable" source of electricity releases CO_2e emissions at a per-kilowatt hour rate that is about seven times higher than the average kilowatt hour of electricity produced in Maine.

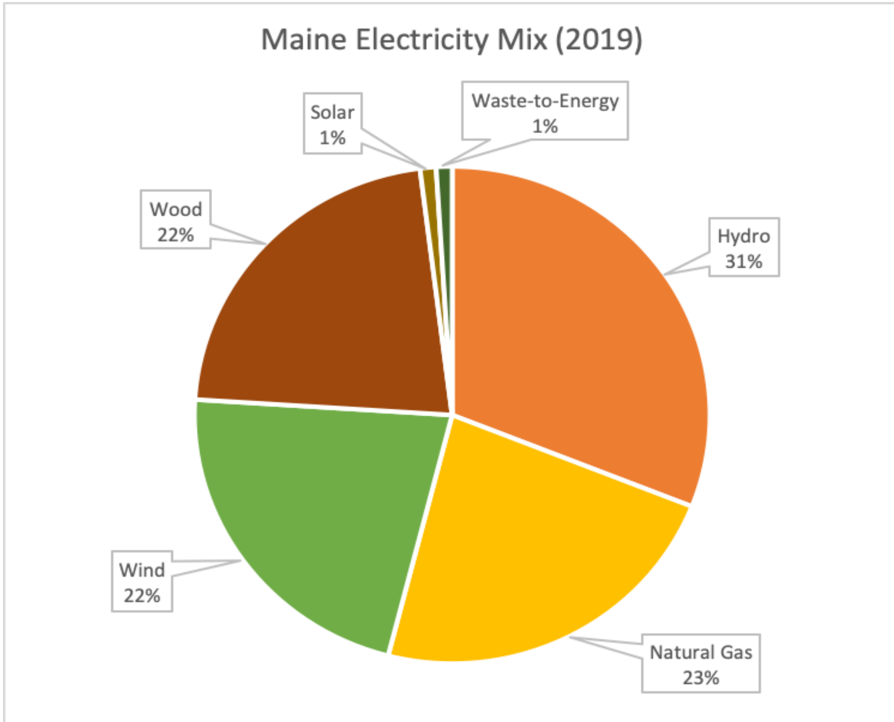

Figure 4: Maine's 2019 electricity mix.

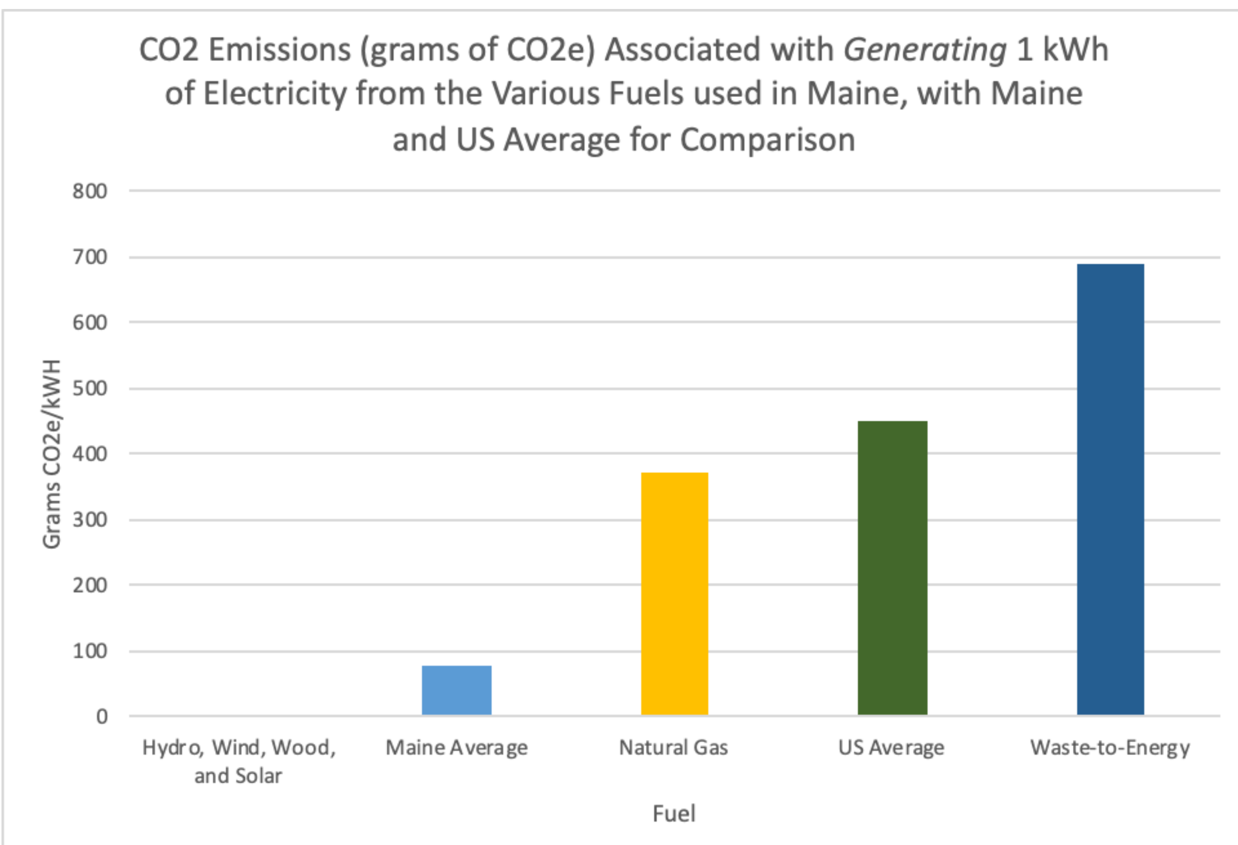

Figure 5: CO2 emissions associated with generating 1 kWh of electricity from the fuels used in Maine, with Maine and U.S. averages for comparison.

4.3: Four Waste Management Scenarios for Auburn

4.3.1: Introducing the Scenarios

From the information compiled about the different materials, it is clear that there are a variety of factors that need to be considered when deciding which waste management strategy should be used for each form of waste. Matching each material with different management strategies creates scenarios that each have different strengths and weaknesses. Clearly, there is a limit to the number of realistic scenarios that can be created and there are certain strategies that cannot be considered for every material. For example, the only material that will be considered compostable is organic matter. By eliminating the possibility of certain materials to reach each of the end locations it will start to become clear what Auburn's options truly are. The options that are available to Auburn will be represented as scenarios where each material is matched with a different management strategy. The scenarios that will be presented will maximize economic efficiency, environmental efficiency or political feasibility for Auburn (Table 2). Presenting scenarios in this way will allow the Auburn city council to balance different factors to help make their waste management decision.

Scenario	Composting	Recycling	Cost	Environmental Benefit
1. Continue Recycling Program	✗	✓	$$$	🌲🌲🌲
2. Implement Composting	✓	✓	$$$$	🌲🌲🌲🌲
3. Replace Recycling with Composting	✓	✗	$	🌲🌲
4. Eliminate Recycling	✗	✗	$$	🌲

Table 2: Four waste management scenarios available to Auburn.

4.3.2: Descriptions of Four Waste Management Scenarios

Status Quo

An evaluation of the costs and environmental benefits associated with Auburn's current waste management strategies will provide a useful baseline for comparing scenarios. Auburn currently recycles metal, glass, plastic and paper with Casella Waste systems in Lewiston, while organic waste and municipal waste would be sent to Maine Waste-to-Energy to be incinerated. It should also be noted that with the current systems recycling rate at about 8%, a significant amount of recyclable materials get sent to MWE where they incinerate what they can and send the excess material to the landfill (currently about 10% of the total waste they receive) (personal communication, Ralph Harder, 2/12/20).

Scenario 1 - Continue and Expand Recycling Program

This scenario assumes that Auburn decides to keep its recycling program, then implements an educational outreach program to increase participation and decrease contamination. Such a program could plausibly increase Auburn's recycling rate to 25-30% within a few years (personal communication, Lissa Bitterman, 4/2/2020), which is what this scenario assumes for calculating costs and environmental impacts. This scenario would be aided by a new contract, particularly one through EcoMaine, as this would transfer some of the educational burden away from city officials.

Scenario 2 - Implement a Composting Program

The second scenario assumes that Auburn implements the expanded recycling program described in Scenario 1, plus a composting program, perhaps with We Compost It!. The implementation of a composting system could take on a variety of different forms: Curbside pickup would be the costliest but also the most effective at diverting waste, while a network of collection locations could increase composting substantially and require very few resources to maintain. Based on the experiences of other cities with composting programs (Portland, Kennebunk, and Brunswick), it is likely that Auburn could achieve a 15-20% composting rate, which is what is assumed for the cost and emissions calculations under this scenario. Within this scenario, it is also assumed that by composting, there would be a decrease in the amount of waste being sent to be incinerated by Maine Waste-to-Energy. Doing this could address overcapacity issues at MWE and partially or completely eliminate the need to landfill excess materials.

Scenario 3 - Replace Recycling with Composting

The third scenario makes the same assumptions about composting as Scenario 2 but assumes that Auburn's recycling program is eliminated. This would therefore require Maine Waste-to-Energy to incinerate all non-metal recyclables. The degree to which this scenario would rely on MWE depends on the assumptions made about composting participation: High participation could easily result in less waste being sent to MWE (if the composting rate was higher than 8%), while low participation could necessitate more incineration.

Scenario 4 - Eliminate Recycling

The fourth scenario assumes that Auburn's recycling program is eliminated as in Scenario 3 without the addition of composting. The increased reliance on Maine Waste-to-Energy required under this scenario would increase the amount of waste that would be sent to the Lewiston Landfill, due to overcapacity issues at MWE. Thus, this scenario considers the environmental and economic costs of incinerating about 80% of Auburn's waste and landfilling the remaining 20% (which is the approximate percentage of Auburn's waste that the incinerator would be unable to process) (personal communication, Ralph Harder, 2/12/20).

4.3.3: Comparing the Economic and Environmental Impacts of the Four Scenarios

Each scenario results in different associated costs and greenhouse gas emissions (Figure 6). The current scenario costs Auburn just under \$1.1 million annually and results in about 9000 tons of CO2e emissions (Figure 6). Scenario 1, which assumes that Auburn's recycling program is continued and expanded, results in an approximately \$75,000 increase in the annual costs associated with both collection and processing. This scenario would also reduce the greenhouse gas emissions associated with waste management in Auburn from about 9000 tons to about 2000 tons CO2e per year, a more than 75% reduction (Figure 6). Scenario 2, which assumes that

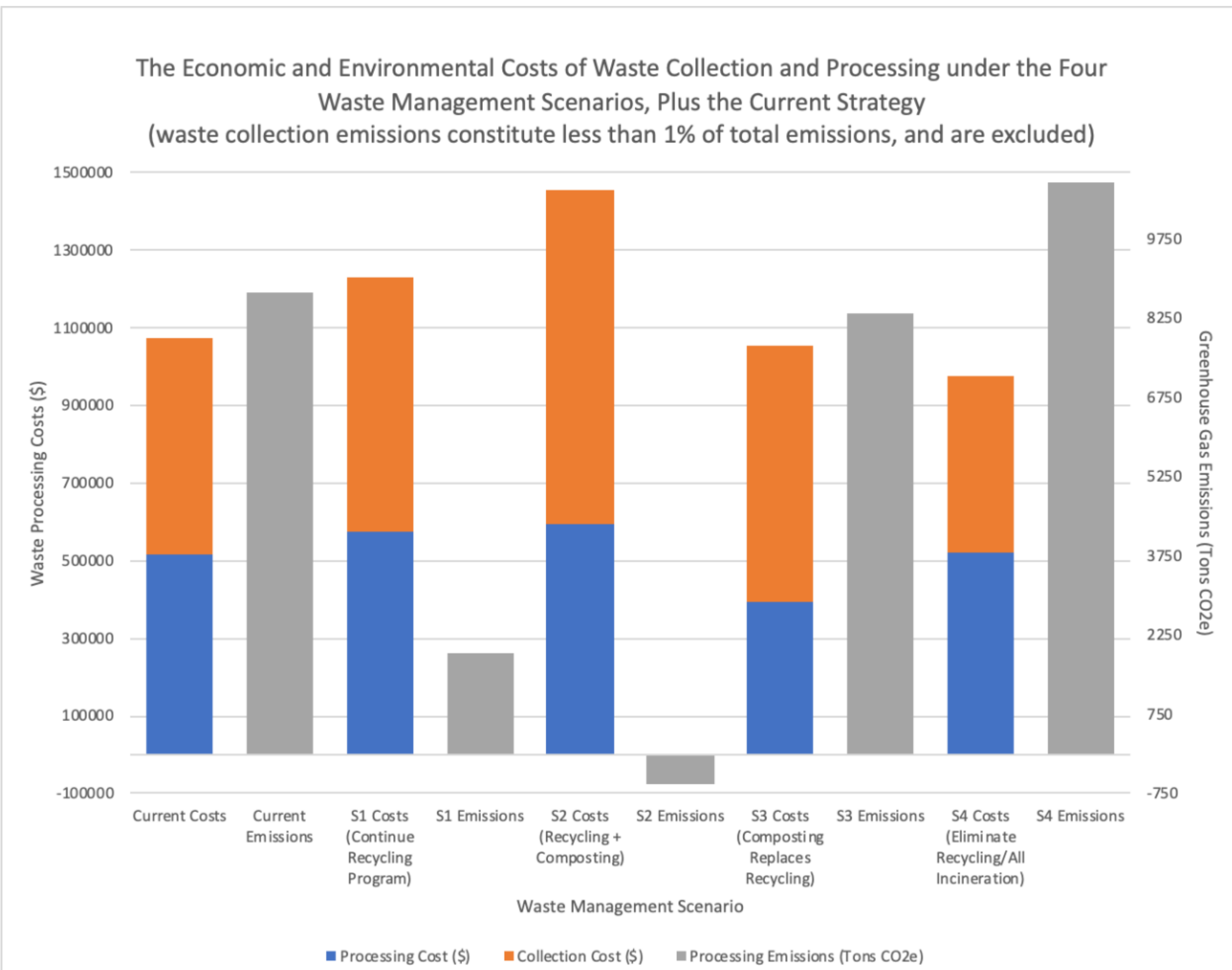

Figure 6: The economic and environmental costs of waste collection and processing under the four scenarios.

Auburn implements Scenario 1 plus a composting program, increases collection costs by about $150,000 over Scenario 1, but results in net-negative emissions for Auburn (about -600 tons CO2e per year) (Figure 6). Scenario 3, which assumes that Auburn eliminates recycling and implements composting, results in an approximately $50,000 decrease in total costs from the current scenario and also results in a slight decrease in emissions, from about 9000 to about 8300 tons CO2e per year (Figure 6). Finally, Scenario 4, which assumes that Auburn eliminates its recycling program, results in an approximately $150,000 reduction in total costs compared to the current scenario. This scenario also results in by far the highest emissions, however: 10,500 tons CO2e per year (Figure 6).

5: Recommendations for Next Steps

Our research suggests that three key actions could dramatically reduce Auburn's waste management-related greenhouse gas emissions without costing the city substantially more money. We understand that cost will be the key determinant of which policy is implemented, which is why none of our proposals would require more than a 10% increase in Auburn's annual waste management budget. This rules out Scenario 2 (the recycling + curbside composting option), but still leaves multiple paths to approaching net-zero waste management emissions within a few years. We hope that these three recommendations will serve as a starting point in Auburn's pursuit of an improved waste management strategy.

Recommendation 1: Use EcoMaine instead of Casella

We believe that Casella, Auburn's current recycling contractor, is partially responsible for the city's low recycling rate. Casella does not appear to have demonstrated any interest in boosting the city's recycling rate, nor has it been willing to invest any of its substantial profits into better equipment or education. Luckily for Auburn, EcoMaine is an alternative which offers far better services at the same price. Like any market, the market for recyclables is a free market: in this case, EcoMaine offers better services, meaning that Casella does not deserve Auburn's business. A large part of the issue with Casella likely has to do with the fact that it is a for-profit company. In principle, we have no problem with turning a profit or making money, but when it comes to sectors of the economy like recycling, we believe that it is more beneficial to Auburn to use a nonprofit organization like EcoMaine, which invests its profits into educational outreach, than a for-profit company like Casella, which uses its profits to pay shareholders.

Quite simply, EcoMaine could offer Auburn more and better service for the same price (EcoMaine charges $115/ton while Casella charges $117/ton). Several factors make EcoMaine a better choice. First, EcoMaine is a nonprofit organization driven by a mission to be financially responsible to be one of the most advanced recycling facilities in the country, and to be a national model for public awareness and educational outreach. Secondly, EcoMaine accepts *and actually recycles* all recyclable commodities, including plastics 3-7, which Casella does not currently recycle (it collects these plastics but ultimately incinerates or landfills them) (personal communication, Ralph Harder, 2/12/2020). If Auburn is going to pay additional money to recycle waste instead of incinerate or landfill it, the city should ensure that this waste is actually being recycled. Third, EcoMaine's educational program works. It offers waste audits, presentations to community groups, "lunch and learns" at an array of organizations and businesses, library programs, public works programs, and programs in schools. These programs consistently result in EcoMaine communities having some of the highest recycling rates and lowest contamination rates in the country: Member communities routinely see contamination rate drop from 20% to 5% following waste audits, for example (personal communication, Lissa Bitterman, 4/2/2020). Two issues Auburn would have to resolve include collection (EcoMaine does not collect waste, though Casella could retain the collection contract) and transportation to the EcoMaine facility in Westbrook. We believe both of these issues are relatively minor, given the benefits. If well-implemented, we believe that switching to EcoMaine would result in a situation similar to Scenario 1: About $100,000 in additional costs (mostly driven by increased recycling volume), a 75-80% reduction in net-emissions, and a recycling rate of 25-30%.

RECOMMENDATION 2: CONSIDER A COMPOSTING PROGRAM

Though a curbside composting program as outlined in Scenario 2 is likely to be too expensive, there are other options which may result in a lower composting rate, but which would still have a substantial positive effect. The most cost-effective solution would be to create a network of compost drop-off facilities around Auburn where citizens could bring their organic waste and implement an education program about composting as part of the education program suggested in Recommendation 3. This program could be implemented in partnership with Auburn farmers, who may welcome additional compostables and be willing to offer space for drop-off facilities. There would be up-front costs associated with creating the compost drop-off facilities and implementing the education program, but this option could save the city money in the long-term as composting with companies like Auburn-based We Compost It! is actually marginally cheaper than incinerating waste with Maine Waste-to-Energy, and composting at local farms could cost the city nothing (Figure 1). Achieving a composting rate of about 10% plus the recycling scenario outlined in the first recommendation would allow Auburn's waste management greenhouse gas emissions to be carbon neutral; increasing the composting rate to 15-20% (or increasing the recycling rate to about 35%) would allow the city's waste management greenhouse gas emissions to be negative.

RECOMMENDATION 3: IMPLEMENT AN EDUCATION PROGRAM

Regardless of the decisions that the Recycling Committee and City Council make, we believe that Auburn should develop and implement an education program to inform citizens about changes in the city's waste management system. Erin Bucki and Annie Sedoric have written a report on potential education programs; we recommend using their report as a starting point for this educational program. It is also important to note that much of the burden for this program would be borne by EcoMaine should the city decide to start sending its recyclables there.

A FINAL THOUGHT: EXTENDED PRODUCER RESPONSIBILITY

Given the magnitude of the recycling challenges facing most municipalities nationwide, state and/or federal intervention may be needed. The Maine Legislature is currently considering

LD 1341, an act which would implement extended producer responsibility (EPR). Common in most European countries and Canadian provinces, EPR effectively tells producers of single-use waste: “you make it, you deal with it” (Portland Press Herald Editorial Board 2020). Under EPR, producers of single-use waste would be required to pay for the disposal of the products they produce based on the ease with which a product can be disposed. EPR would shift the more than $17 million which Maine municipalities spend annually on waste management to the producers of single-use waste. This system also incentivizes producers to use the most environmentally responsible packaging possible and spurs innovation in packaging manufacturing, because producers are charged less for more environmentally responsible packaging (Portland Press Herald Editorial Board 2020). If implemented, EPR would resolve most of the state’s waste management challenges (Portland Press Herald Editorial Board 2020), including those facing Auburn. Though LD 1341 is unlikely to be passed this year, we believe that the Auburn City Council should endorse this legislation and urge its state delegation to support this bill should it be resurrected next year.

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APPENDICES

APPENDIX A: THE QUESTIONS WE ASKED IN OUR CONVERSATIONS WITH LOCAL WASTE MANAGEMENT ORGANIZATION REPRESENTATIVES

1. Members of the *Auburn Recycling Committee*, including Ralph Harder and Camille Parrish, both of whom have a wealth of knowledge about local waste management issues.
   i. What scenarios do you envision being palatable (economically, environmentally, and politically)?
   ii. What has Auburn already tried?
   iii. How much additional money do you think the city willing to spend on waste management?
   iv. Are returnables on a completely different track, or do some residents also put returnables in the city recycling bins?

2. *Maine Waste-to-Energy*, the trash incinerator for many towns in the Androscoggin River Valley, including Auburn.
   i. What do you know about emissions, electricity production potential and recyclability of different materials (e.g., glass, paper, metal etc.)?
   ii. How much additional waste can you process (would some be landfill)?
   iii. What materials are and are not acceptable?
   iv. How great is your capacity to sort materials? Could you, for example, sort out metal and glass for recycling?

3. *Casella Waste Systems*, the zero-sort recycling facility in Lewiston, which handles Auburn's recyclables.
   i. What is the recyclability and value of different materials? Can some materials still be sold despite recent market changes? Is there a cost associated with recycling other materials?
   ii. What materials can you and can't you accept?
   iii. How much sorting are individuals expected to do?
   iv. What materials are actually recycled? Are there some materials for which "recycling" means incineration?
   v. Do you process returnable bottles and cans? If so, are they coming in separately or do many come in with non-returnable recyclables?

4. Auburn-based *We Compost It!*, a local composting facility which accepts both household compost and compost from larger facilities like the Bates dining hall.
   i. What have composting programs in other municipalities looked like?
   ii. How much would it cost to implement curbside composting in a city like Auburn?
   iii. What can you compost, and what is unacceptable?
   iv. How great is your capacity to sort what you receive? How clean would the compostable materials need to be for them to be compostable?

5. *EcoMaine* in Westbrook, the recycling and incineration facility serving most of southern Maine.
    i. Is EcoMaine currently accepting waste from additional towns?
    ii. What recyclables does EcoMaine process?
    iii. How effective is EcoMaine's educational outreach program? How rapidly and substantially could it increase Auburn's recycling rate?
    iv. What are EcoMaine's tipping fees?